Weatherwise

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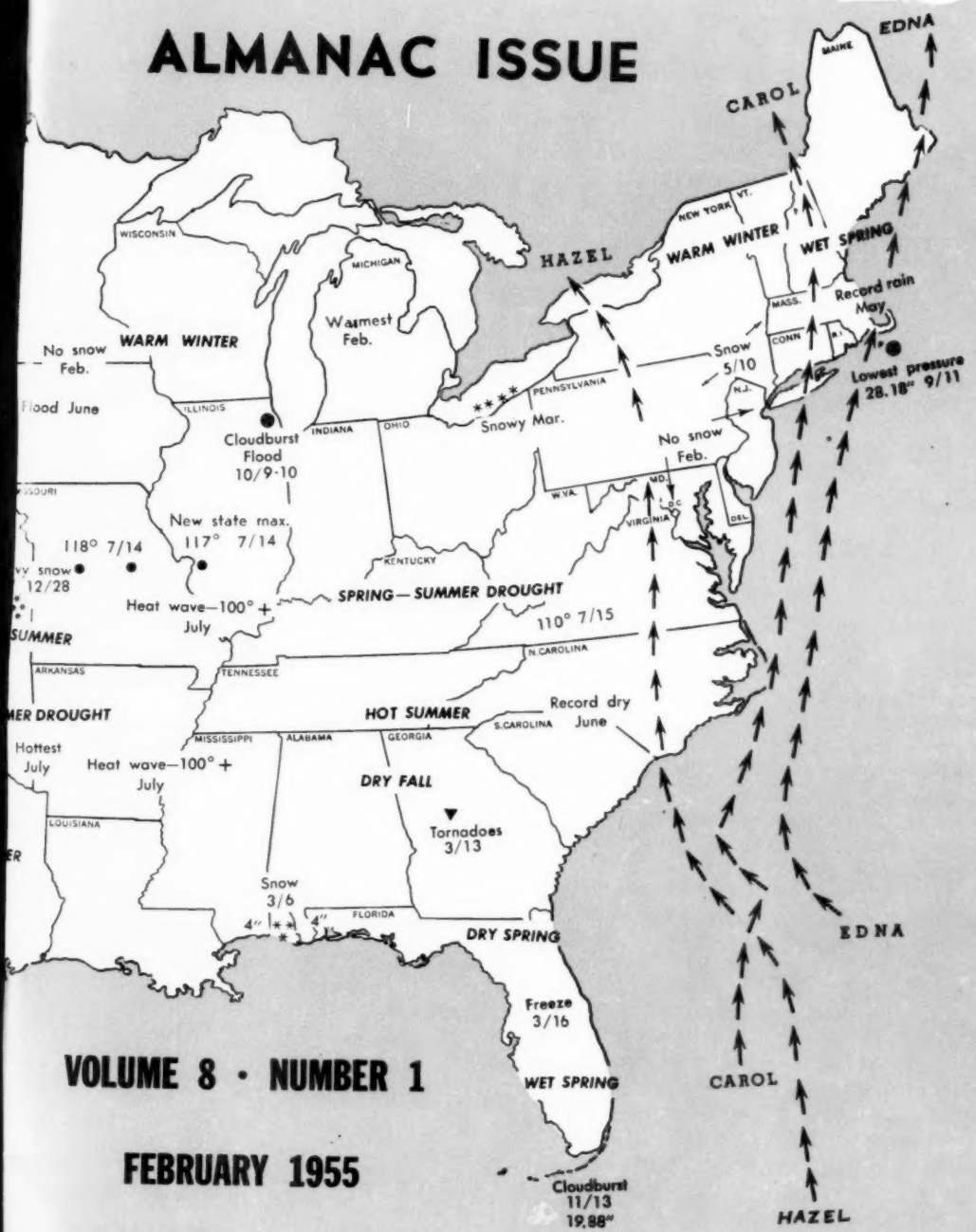

VOLUME 8 · NUMBER 1

FEBRUARY 1955

"SOME PEOPLE ARE WEATHERWISE BUT MOST ARE OTHERWISE"—BENJAMIN FRANKLIN

WEATHERWISE

THE MAGAZINE ABOUT WEATHER

DAVID M. LUDLUM, *Editor* HENRY W. BULKLEY, *Associate Editor*

New Year's Greeting from President Merewether

AS we move into this New Year of 1955, it gives me much pleasure to extend greetings on behalf of the officers and councilors to all the members of our Society. January, named for the two-faced Roman God Janus, is the traditional month for taking stock of where we've been and looking forward to where we're going.

The past year has been a good one for the Society. Financially we are as strong, if not stronger, than ever. In membership we have continued to grow, and our enrollment is now well over 5000. The Society has held a number of very successful meetings throughout the country, and the papers presented at all these gatherings continue to be of high caliber.

The science of meteorology is one in which advances are apt to be slow and undramatic, quite unlike the spectacular results in nuclear physics, aviation, or electronics. Nevertheless, progress is being made. A better understanding of the general circulation exists now than ever before, advances are being made in cloud physics, numerical forecasting is about to become a factor to be reckoned with, studies are progressing in bioclimatology—just to mention a few of the many phases of the weather problem that are being successfully attacked. Rain making is still a controversial subject, what makes tornadoes and hurricanes tick remains an unsolved mystery, long range forecasting is still in the relatively early stages of development. Yes, there are plenty of difficult, unsolved problems to keep meteorologists busy for untold years in the future.

Our Society has been established to encourage the development of meteorological knowledge, and the advancement of professional ideals among meteorologists. It is our earnest hope that these objectives will continually act as an inspiration to our members. The American Meteorological Society is young as worldly organizations go, celebrating this year only its 35th birthday. But if we continue to grow and prosper in the future as we have in the past, and I see no reason why we should not, then our objectives are assured, and we can look forward to many more years of accomplishment for our Society and its members.

A. F. MEREWETHER

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The Meteorological Year of 1954

IVAN TANNEHILL, *U. S. Weather Bureau, retired*

EVERY year has record-breaking weather somewhere in the United States. Anomolous weather, therefore, is not unusual, but the year 1954 was outstanding in four respects. It began with a mild winter that culminated in nation-wide warmth in February, though in the middle of this mildness there was a brief spell of extremely cold weather. On the chart of mean temperatures for January this spell left a negative departure shaped like a giant footprint with its toes in the southern Plains and its heel in Montana, where Rogers Pass had a low temperature of 69.7° below zero on 20 January, the lowest official temperature ever recorded in the United States. The previous record was − 66° in Yellowstone National Park on 9 February 1933.

The records were shattered in another way. Because of the extreme interest in tornado forecasting and the recent increase in the number of network observers, it was expected that many tornadoes would be reported. The year 1953 had broken all previous records with more than 500, but the number in 1954 exceeded the most optimistic expectations. At the end of December the count was above the 700 mark. This seems to point rather definitely to the conclusion that meteorological conditions have been unusually favorable for severe local storms, a fact which is not easy to understand. The inflow of warm, moist air into the continent east of the Rockies, accepted as one of the requirements, was below normal in the region of greatest frequency. On the other hand, the loss of life and damage to property in 1954 was much less than in 1953.

Although the number of hurricanes was not excessive, property damage sky-rocketed to a new record, probably reaching a figure in excess of $750 million. Hurricanes Carol, Edna, and Hazel affected populous regions and caused enormous damage to residential property, creating a very serious problem for insurance underwriters. In New England and on Long Island the insurance claims for one day exceeded the average for the whole United States for a full year.

In a fourth respect the year broke many records. Drought and summer heat continued for the third year in rather large areas, establishing new records of persistent dryness. As one example, Little Rock in the summer months ending with August recorded 43 days with temperature above 100° and had only 23% of normal rainfall.

The combination of drought, rainfall, and a few record-breaking local floods lent support to public apprehension of the weather-deteriorating effects of nuclear explosions and to statements in the press that the warming trend in the present century is causing hurricanes to take paths farther to the northward as demonstrated by the courses taken by hurricanes Carol, Edna, and Hazel.

Claims regarding atomic effects entered the international field. By mid-year the Japanese Meteorological Society was claiming serious deterioration of the weather and had sent statements and resolutions to all weather services in the world urging action toward the elimination of all atomic and hydrogen bomb activity. Their material came before the executive committee of the World Meteorological Organization meeting in Geneva in September. After much discussion the committee instructed the Secretary General to make an investigation and report to the organization in 1955.

The Japanese also came to the front in the international field with a symposium on ty-

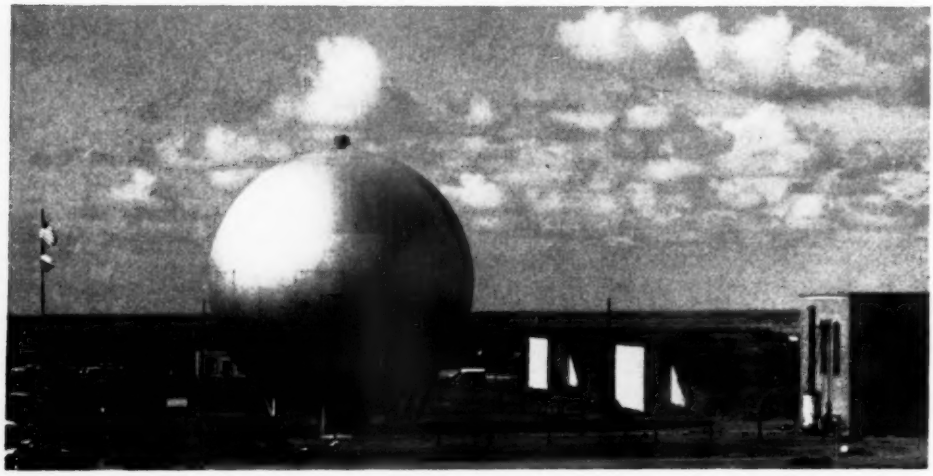
phoons held in Tokyo in the autumn. It was attended by 44 representatives of 13 nations interested in tropical cyclones, including 15 from this country, mostly from Pacific and Far Eastern assignments, but six experts traveled from continental United States. Arrangements for the meeting including travel were made by the Japanese through UNESCO.

On the international front there were two other items of general interest. During the year the job of preparing daily synoptic charts of the Southern Hemisphere was transferred from the United States to the Union of South Africa. These charts were begun in Boston in 1949 as a joint project of the Weather Bureau and Massachusetts Institute of Technology; later the work was taken over by the Weather Bureau in Boston. In August 1954 the work was shifted to the Meteorological Office in Pretoria. This project provided the first world maps on a daily basis by combining the charts of the two hemispheres. The assured continuation of the work keeps open the opportunities for current and future studies of large-scale weather changes of world scope.

During 1954 all weather services in the world were occupied in printing instructions for the numerous changes in international codes that were effective 1 January 1955. While none of the 1947 codes was completely overhauled, there were many changes, especially in the aviation forms. Many improvements in the communication of weather observations, analyses, forecasts, and other information are confidently expected. In the United States the instructions were drawn up jointly by the Weather Bureau, Air Weather Service, and Navy Aerological Service.

From the historical viewpoint the outstanding action on the domestic front was the official beginning on 1 July 1954 of Joint Numerical Weather Prediction (JNWP). Organized under a joint agreement of the Air Force, Navy, and Weather Bureau to share equally the costs and professional complements, the unit began preliminary operation during the year. The electronic computer especially adapted to meteorological work will be delivered by the International Business Machines Corporation about 1 March 1955. Meantime the unit is busily engaged in developing the necessary techniques. Prognostics will be furnished once a day to the new National Weather Services Analysis Center at Suitland, Maryland, as soon as the computer is in operation.

Ultimately, three fundamental requirements for numerical weather operations will be a set of weather codes containing the essential data, a means of communication capable of rapid delivery, and a revision of observing networks to include automatic weather stations. There



The giant experimental cloud chamber of the Physical Research Division, U. S. Weather Bureau, at Hitchcock, Texas.

An electronic data processing machine, International Business Machine No. 701, similar to a type to be employed at the new Joint Numerical Weather Prediction project at Suitland, Maryland.

were preliminary advances in these general directions in 1954. Research and test work were continued on an electronic communication system capable of delivering at a minimum rate of 600 words a minute, a system having ample capacity to serve numerical operations.

All three weather services announced progress in the development of automatic stations. The Weather Bureau, for example, put into operation during the year two stations which not only take the observations automatically, but enter them in proper code on schedule by teletypewriter in sequence with stations manned by live observers. This is now being done at Park Place in Pennsylvania and at Sandberg in California.

Early in the year the Weather Bureau initiated a research program at the new giant spherical cloud chamber at Hitchcock, Texas. It has a capacity of 3,000 cubic meters with facilities for control of temperature, water vapor content, and rate of expansion of the air in the chamber. This makes possible the production of clouds of various forms by processes nearly identical with those in nature.

The year 1954 was outstanding in the increased publication of contributions to meteorology, and in the initiation of new research by the universities, the airlines, industrial meteorology firms, and by individuals intrigued by the opportunities of the meteorological field. Because of the great complexity of the over-all meteorological problem, nearly every solution to a puzzling phase of the problem brought forth two or three new questions requiring further expansion in the fields of research and operational techniques. Of this grand puzzle there are thousands of small pieces on which the year saw an increasing army of enthusiasts at work, with demands for more frequent national and local meetings, special conferences, and longer programs in order to present the results of their labors and benefit by the discussions. Mention of these many activities and their evaluation are beyond present space limits, but they highlight an important trend during the year.

The General Circulation of 1954*

WILLIAM H. KLEIN, *Extended Forecast Section, U. S. Weather Bureau, Washington, D. C.*

WINTER AND SPRING

FROM December 1953 to June 1954 a pronounced 2-month cycle characterized the weather and circulation of the eastern two-thirds of the United States. During the months of December, February, April, and June heights at 700 mb (approximately 10,000 ft.) and temperatures at the surface averaged above normal in most of this area. During each of these months the zonal index, which expresses the strength of the prevailing westerlies at middle latitudes of the Western Hemisphere in the mid-troposphere, was above its normal value (fig. 1, bottom), and the axis of the west wind belt was displaced northward (except June) (fig. 1, top). Fast westerly flow along the United States–Canadian border prevented cold continental air from penetrating the United States, and the principal storm track was confined to Canada. On the other

* For a more complete discussion the reader is referred to the series of articles on the weather and circulation of each month appearing regularly in the *Monthly Weather Review*.

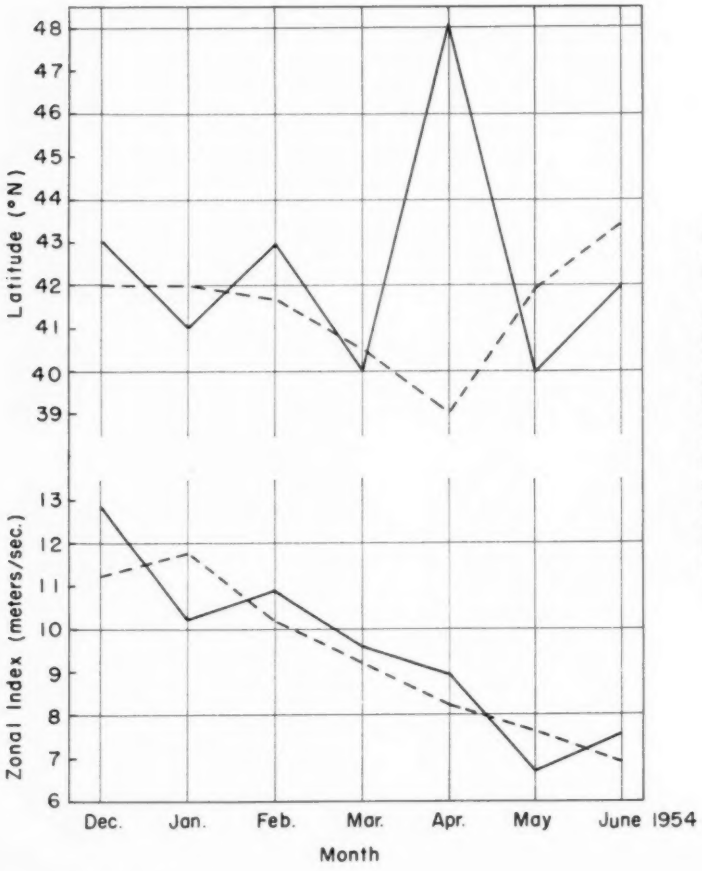


FIG. 1. The top chart shows the oscillations in the latitude of the strongest west wind component on the monthly mean 700 mb maps from December 1953 to June 1954. The normal for the period is indicated by a dashed line. The bottom chart illustrates the oscillations in strength of the west wind component on the mean monthly 700 mb zonal index for the Western Hemisphere in the latitude belt 35° to 55° N for the same period.

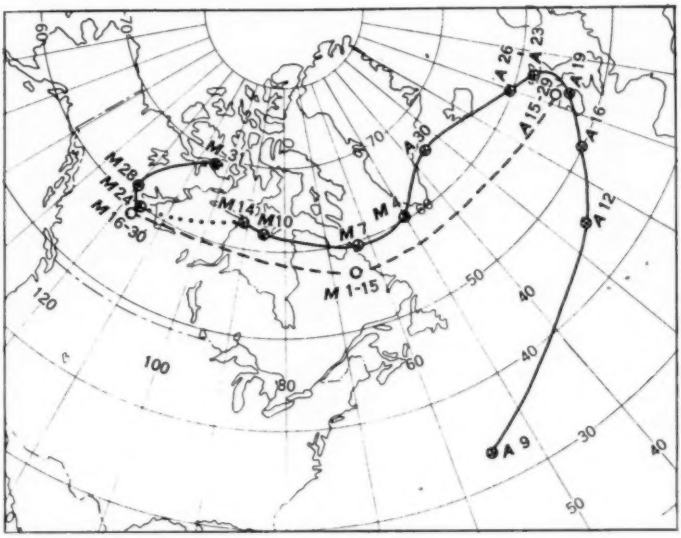


FIG. 2. Trajectory of the 700 mb anticyclone of April and May 1954, as determined from a series of 15-day mean charts (dashed track) and 5-day mean charts (solid track except dotted in region of uncertain continuity). Open circles locate the center of the 15-day mean anticyclone starting with the period April 15–29 and ending with the period May 16–30. Crossed circles indicate the center on successive 5-day mean maps (computed twice-weekly) from the period centered April 9 (A9) to the period centered May 31 (M31).

hand, relatively cool weather and low heights in the eastern United States during January, March, and May were accompanied by below normal values of the zonal index (except March) and southward displacement of the strongest westerlies and major cyclonic activity to lower latitudes than normal. Recurrent large-scale blocking and strong meridional flow intensified storminess and produced frequent polar outbreaks in the United States during these three months.

One of the most extreme of the six month-to-month circulation reversals which occurred during the first half of 1954 was that from April to May, when the latitude of the maximum westerlies decreased from 48° to 40° N., against the normal trend (fig. 1, top), and the zonal index dropped by 2 meters per second (fig. 1, bottom). This reversal was effected, in large part, by an unusually long-lived blocking anticyclone which dominated the hemispheric circulation for almost two months.

The remarkable track of this anticyclone at the 700 mb level on a series of 15-day and 5-day mean charts is shown in figure 2. The 5-day mean high first appeared just east of Bermuda during the period centered 9 April. For a week and a half it was embedded in a fast westerly steering current and moved rapidly northeastward along a rather common trajectory. After stagnating near the British Isles for a week, it began to recurve toward the northwest in a great cyclonic loop. Upon reaching latitude 60° N., north of the main westerly stream, it retrograded steadily for almost two weeks across the Denmark and Davis Straits into Hudson Bay. Up to this point its continuity, although unusual, could clearly be followed on our series of twice-weekly overlapping 5-day mean charts. However, for a week following the period centered 14 May only broad ridge conditions could be detected in Canada, and a separate high cell did not reappear on our charts until the 5-day period centered 24 May. This portion of the track has therefore been dotted in figure 2. During the last week of May the anticyclone was again well defined as it moved through western Canada, first northwestward and then northeastward.

On a daily basis the continuity of the anticyclone was not so clear since several eastward-moving daily systems made up the retrograding high, as is usually the case. It is rare, however, for a blocking anticyclone, even on a 5-day mean basis, to retrograde bodily from England into western Canada, as this one did. It is more customary for blocking to spread westward by means of successive intensification of ridges and weakening of troughs upstream, as occurred earlier this year

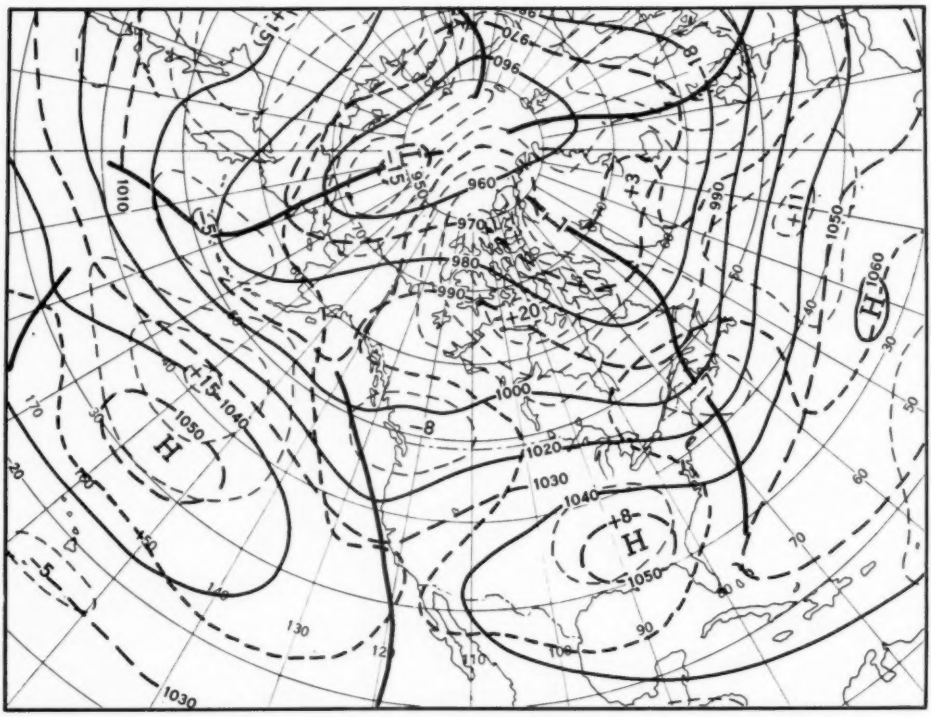


FIG. 3. Mean 700 mb contours (solid) and height departures from normal (dashed), both in tens of feet, for summer (June, July, and August) of 1954. Marked month-to-month persistence of many circulation features makes this chart very representative of the prevailing circulation of the summer and early fall.

during the pronounced blocking waves of January and March.

SUMMER AND EARLY FALL

The sequence of monthly oscillations characterizing winter and spring ended abruptly in June. Instead the large-scale circulation pattern established during the second week of that month persisted with little change throughout the summer and early fall. In fact, visual inspection of all mean 700 mb charts for summer and fall revealed that no other year in the entire period of record (back to 1933) exhibited anywhere near the degree of persistence observed this year over the Western Hemisphere. This stable regime is well portrayed by the seasonal mean map for summer, shown in figure 3, and consisted of deeper than normal troughs along the east and west coasts of the United States as well as in the west-central Pacific and European areas, separated by stronger than normal ridges in central parts of the Atlantic, Pacific, and North America. The unusual stability of this planetary wave pattern may be related to the fact that *all* troughs and ridges were located close to their normal positions, where monthly mean troughs and ridges have been most frequent in previous summers. As one consequence of this hemispheric persistence, the British Isles, close to the center of the largest negative height anomaly of figure 3, experienced one of the coldest and stormiest summers in its history.

In the United States the dominant feature of the summer circulation was an abnormally strong upper-level continental anticyclone centered on the Alabama-Mississippi border in the mean chart (fig. 3). Although this anticyclone fluctuated somewhat in intensity and position from week to week, it was located

somewhere in the southern half of the country east of the Rocky Mountains on all but one 5-day mean 700 mb map from 5 June to 13 October. The association of such a high-level thermal anticyclone with summertime heat and drought over the United States has been pointed out many times since the pioneering studies of T. R. Reed in the 1930's. This year's continental anticyclone was typical of those noted previously: a warm high which increased in intensity with elevation from near normal pressures at sea level to maximum anticyclonic vorticity at the tropopause (200 mb) level. Very few cyclones and fronts were able to push into the southern half of the United States to relieve the regime of record-breaking heat and drought which prevailed underneath the continental anticyclone. The nation's principal cyclonic activity was tropical in origin, as hurricanes Carol, Edna, and Hazel moved up the East Coast trough during periods when it was west of its seasonal mean position.

Late Fall and Early Winter

The passage of hurricane Hazel coincided with a major change in the broad scale circulation pattern which occurred over a period of about one week near the middle of October. During this week troughs replaced ridges in the eastern halves of the United States and the Pacific, while cyclonic flow in the western United States gave way to a ridge. The resulting upper level wave pattern in the United States, consisting of a ridge in the west and a trough in the east, is the one most frequently observed in the cooler months of the year. It proved to be the dominant feature of the circulation during the second half of October and most of November and December. Thus a typical summer circulation of great stability was dramatically replaced by an equally typical and definitive winter type of pattern.

The new circulation pattern is well portrayed in figure 4, showing the mean 700 mb heights and anomalies for the 2-month period

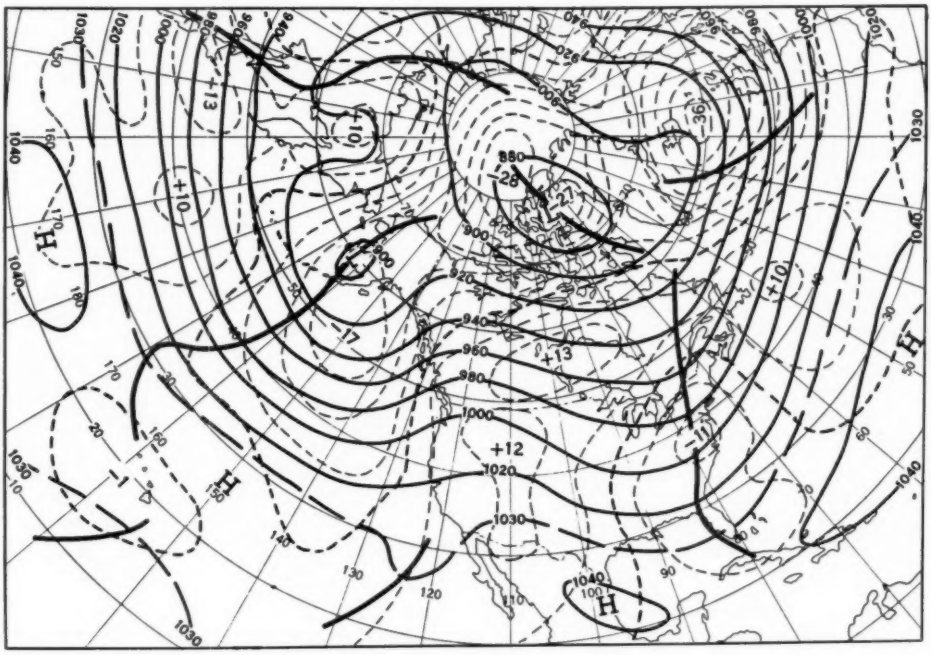


Fig. 4. Mean 700 mb contours (solid) and height departures from normal (dashed) for the two-month period from mid-October to mid-December 1954. This typical winter circulation pattern contrasts sharply with the summer pattern of figure 3.

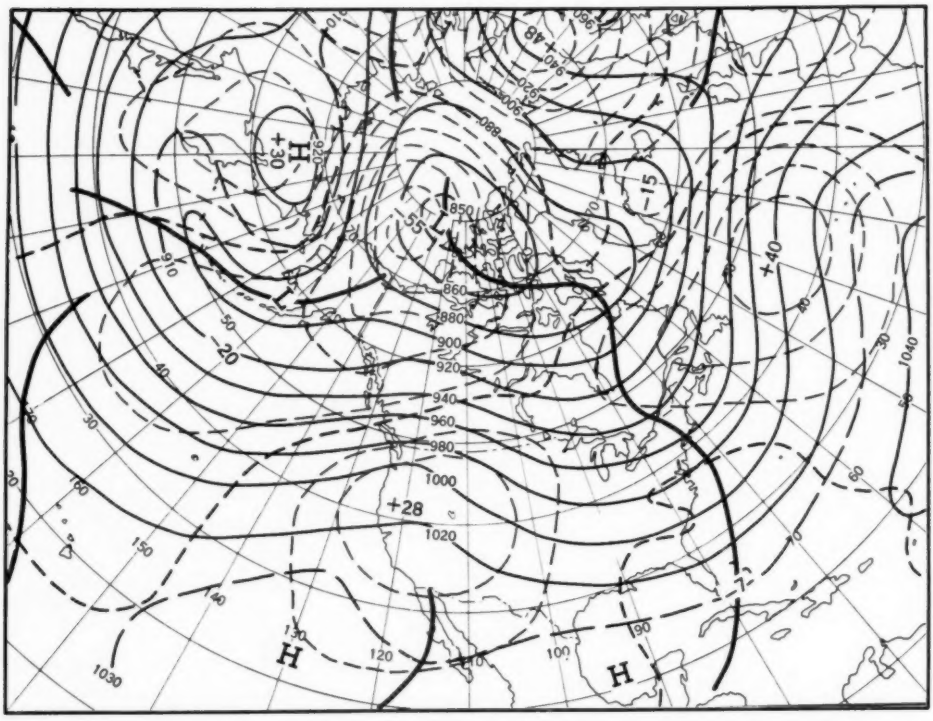


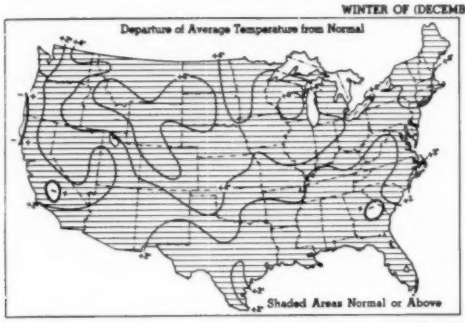
FIG. 5. Mean 700 mb contours (solid) and height departures from normal (dashed) for the month of February 1954. Note the anomalous polar vortex which combined with below normal heights in western Canada and the Gulf of Alaska to produce the warmest February on record in the United States.

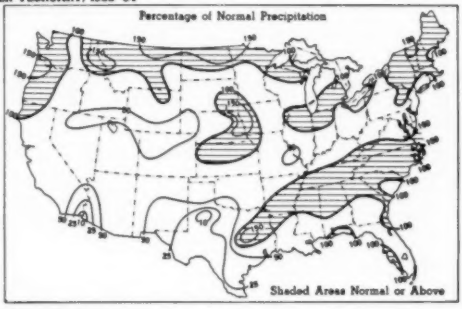
from mid-October to mid-December. The well-defined nature of the upper level wave train of figure 4 was reflected at sea level by such strong centers of action as the Gulf of Alaska Low, Great Basin High, Icelandic Low, and Azores High, all of which were more intense than normal.

As far as the United States is concerned, the principal feature of figure 4 is the stronger than normal northerly flow which produced dry weather in most of the country between the Appalachians and the West Coast Ranges. Temperatures averaged below normal only in the Southeast and Plateau states, however, because the flow of cold cP air was largely cut off by below normal heights and fast westerlies in northwest Canada, Alaska, and the Arctic Ocean to the north. Unusually deep cyclonic activity in this area prevented the formation of strong polar highs in their normal source region and resulted in the western two-thirds of the United States being dominated by relatively mild maritime air masses from the Pacific. Much the same situation prevailed during the month of February 1954, but to a more extreme degree. During that month (fig. 5) a closed low center replaced the normal ridge in the Arctic Ocean north of Alaska, with the resulting anomalies (-550 ft. at 700 mb, -18 mb at the surface) being the lowest ever observed in this region. Largely for this reason, the weighted temperature average for the United States as a whole was higher this February than for any previous February in the 62-year period of record. It was also the only February that had a higher temperature than the following month of March. Thus unusually intense cyclonic activity in the arctic basin was one of the outstanding characteristics of the general circulation of the year 1954.

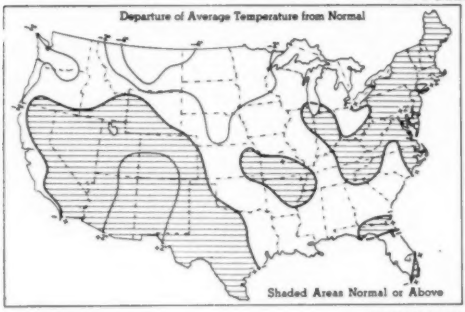
THE WEATHER BY SEASONS 1954

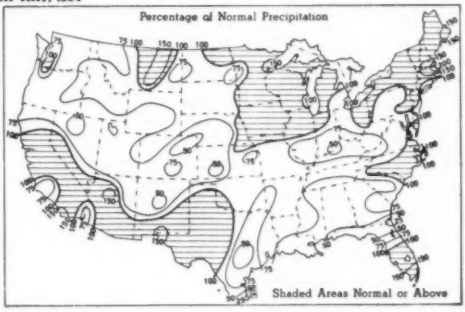
WINTER OF (DECEMBER–FEBRUARY) 1953–54



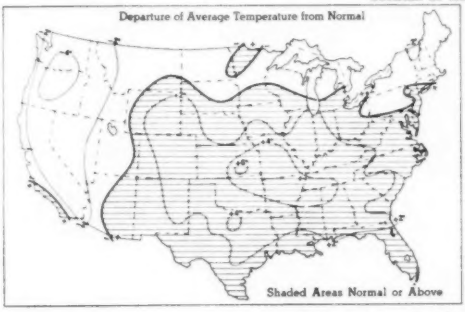


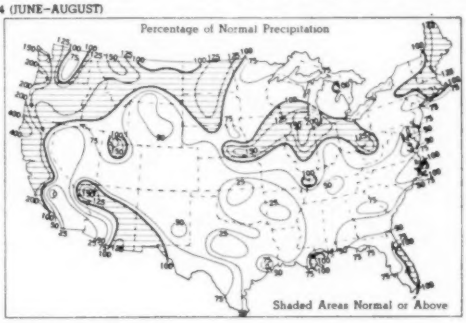
SPRING (MARCH–MAY) 1954



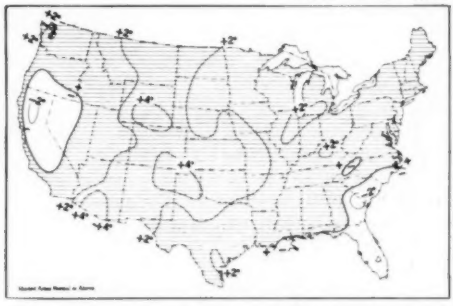


SUMMER OF 1954 (JUNE–AUGUST)

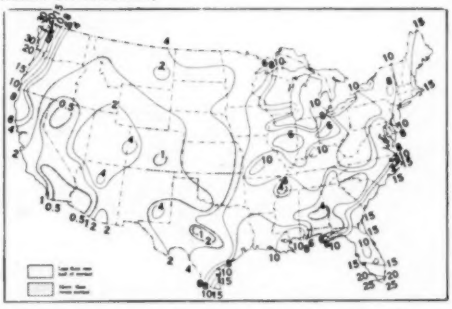




FALL OF 1954 (SEPTEMBER–NOVEMBER)



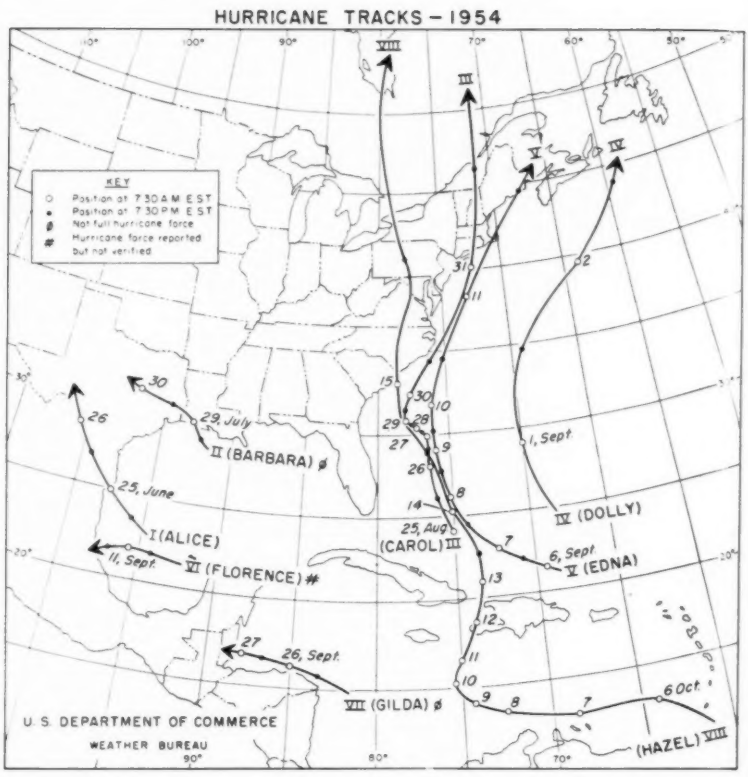
Charts show the departure of the temperature from normal in degrees Fahrenheit by seasons 1954. USWB charts.



Charts show the departure of precipitation from normal by seasons 1954, except chart for the fall which shows total precipitation. USWB charts.

The 1954 Hurricane Season

ROBERT C. GENTRY,
U. S. Weather Bureau,
Miami, Fla.



THE 1954 hurricane season was featured by three important storms, Carol, Edna, and Hazel, which struck the northeastern United States. For the first time in history, New England, heretofore believed largely out of the hurricane belt, had two real hurricanes in one year. By contrast, none of the coast from Texas through Florida to Georgia, the very heart of the United States hurricane belt, was affected by hurricane force winds. Eight tropical storms, six of hurricane intensity, were tracked during the season. This number is about normal, but the storm tracks were very abnormal.

Several new records were set during the season. Property damage in the United States was at an all-time high. Carol caused more damage to property and crops than any previous hurricane of history. Lloyds of London estimated that total damage from the eight storms in all areas of the Western Hemisphere was over $1.35 billion—another record by a sizable sum. Even with incomplete reports from Hazel, we know that more damage was caused in the United States from hurricanes in 1954 than in the preceding 15 years combined. In addition, Hazel, one of the century's great hurricanes, established several individual records which will be listed later.

ALICE

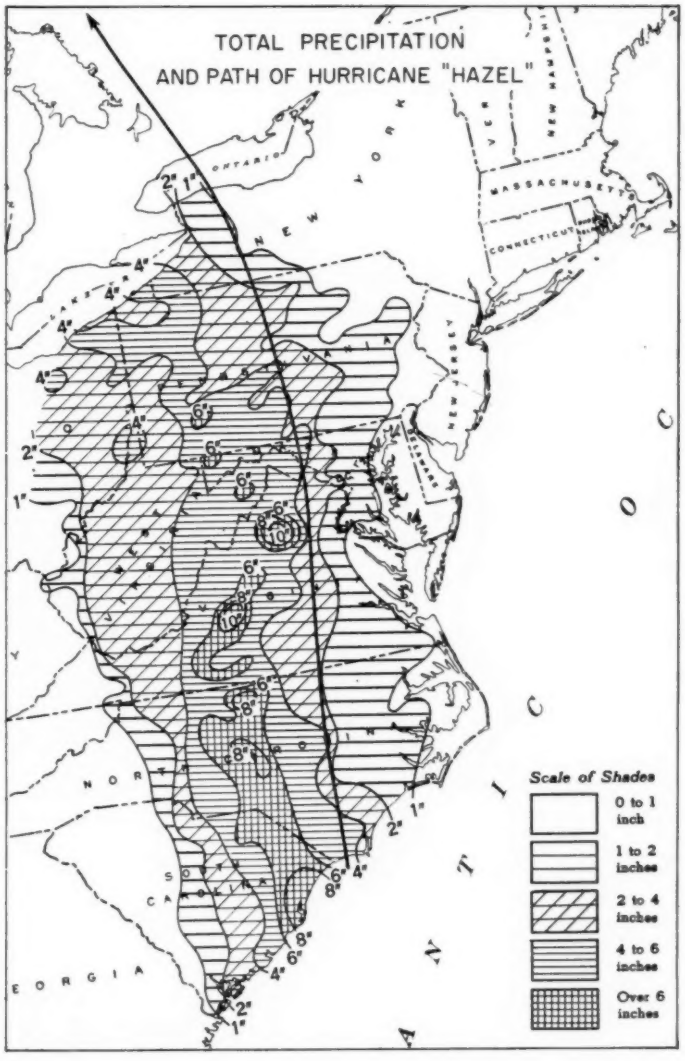
Hurricane Alice, the first of the season, developed rapidly in the West Gulf of Mexico on 24 June in an easterly wave. After moving inland south of Brownsville early on the 25th, she moved up the Rio Grande Valley and passed over Laredo, Texas. This June storm produced the maximum flood of record on the middle Rio Grande and lower Pecos rivers. In one area 26 inches of rain fell during the storm.

Barbara

Barbara, which moved inland in southwestern Louisiana on 29 July, never reached hurricane force and had highest winds of only 60 mph. The winds did little damage and the rains were beneficial.

Carol

Hurricane Carol formed in a weak easterly wave during the night of 26 August and moved to the region of 30° N, 76° W, where it became nearly stationary, moving at a net rate of less than 3 mph for the next 60 hours. Carol accelerated on the 30th and passed to the east of Cape Hatteras, North Carolina, and by noon of 31 August was moving northward at nearly 40 mph. Carol came inshore over east-central Long Island and then bisected central New England from southeastern Connecticut to northeastern New Hampshire. Losses were comparatively light along



The solid line shows the path of Hazel through the Middle Atlantic states. Shaded areas indicate total precipitation on 15–16 October 1954. Note that all the major amounts lie west of the track along the slopes of the Appalachian Mountains.

the Middle Atlantic coast, but were severe on eastern Long Island and in New England. The total damage has been estimated at $460 million, a figure which in dollars exceeds any previous storm. Sixty persons were killed. Highest winds measured during Carol's northward dash were at Block Island, off the coast of Rhode Island, where the extreme speed was 120 mph and the fastest gust 130 mph.

Dolly

Dolly formed in the apex of an easterly wave during the night of 31 August. She moved very rapidly north and northeast, and by the afternoon of 2 September was east of Nova Scotia in the process of losing force and becoming extra-tropical. Strongest winds reported by aircraft were 115 mph on 1 September.

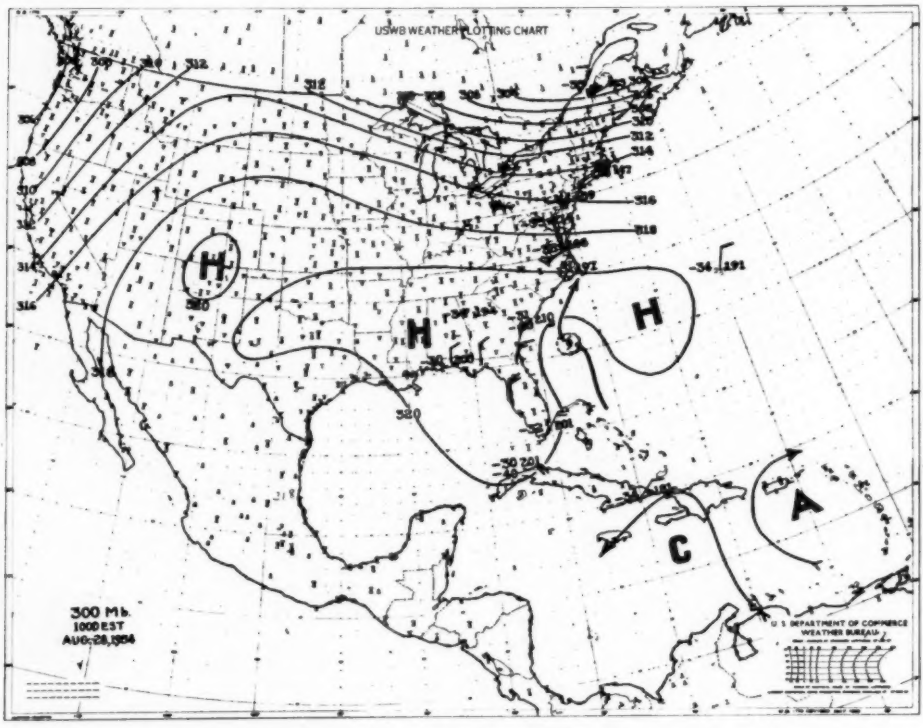
Edna

Hurricane Edna, the second such storm to visit the East Coast within 11 days, struck New England a glancing blow on 11 September. She had formed in an easterly wave on 6 September and increased to hurricane force that night. Although reconnaissance crews indicated that Edna was more intense than Carol, she did not do nearly as much damage because: (1) most of New England was on Edna's relatively weak northern and western sides; (2) Edna passed at time of relatively low tide and the storm tides therefore were not far above mean low water; and (3) Carol had already destroyed most vulnerable property. Fastest winds measured at a land station were 95 mph at Brookhaven National Laboratory on Long Island.

Damage from Edna, estimated at $26 million, occurred principally in New England and Long Island. Sixteen people were killed by the storm.

Florence

Florence formed in the southwest Gulf of Mexico from an easterly wave on 11 Septem-



The pressure contours at 300 mb (approx. 30,000 ft.) at 1000E, 28 August 1954. Isobars numbers indicate hundreds of feet; temperatures at 300 mb are shown to the left of station circles. Carol is east of Jacksonville, Florida.

ber. After just reaching hurricane force, she went inland and dissipated against the mountains of Mexico. Five people were killed in Mexico, and property damage was estimated at $1.5 million.

Gilda

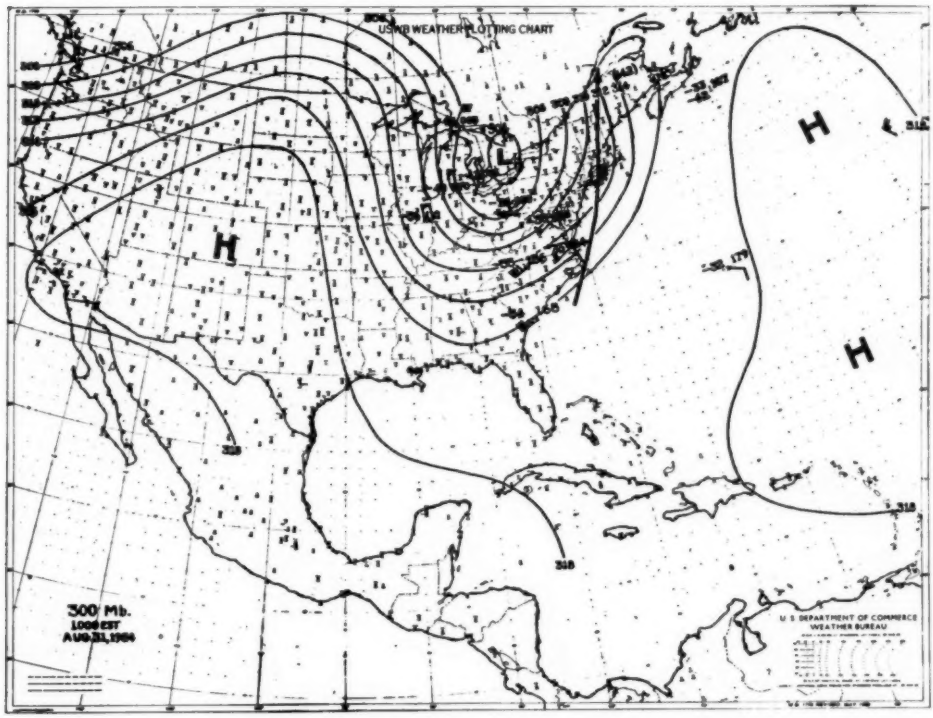
Tropical storm Gilda formed in the western Caribbean Sea area and moved inland in British Honduras before dissipating. Highest winds were 60 to 70 mph. There was some damage but no casualties.

Hazel

A hurricane with winds of 95 mph was located on 5 October at 12.1° N, 61.2° W and was promptly christened Hazel. After passing near the Island of Grenada in the Windward Islands, she spun furiously westward across the Caribbean Sea threatening first Aruba and Curacao and then Jamaica. Finally, on the 11th she crashed across the western tip of Haiti and through the Windward Passage into the Atlantic Ocean. Leaving Haiti battered and flooded, Hazel crossed Great Inagua in the lower Bahamas, moved between Mayaguana and Acklin Islands, and then passed a short distance east of the northwestern Bahama Islands. Hazel caused very little damage in the Bahamas, but she soon accelerated and moved towards the Carolinas at about 25 mph with surface winds steadily increasing to about 130 mph.

Hazel swept into North Carolina near the South Carolina state line at 0915 on 15 October, then battered her way over the northeastern states into Canada after grazing Washington, D. C. with a fury unsurpassed by any previous tropical storm.

The winds of Hazel were awe-inspiring, but the overwhelming wind-driven tides were even more dangerous. Along the Carolina coasts, where wind and wave action combined, the devastation was almost unbelievable. Every fishing pier from Myrtle Beach, South Caro-



The pressure contours at 300 mb (approx. 30,000 ft.) at 1000E, 31 August 1954. Dark line shows the path of Carol then near Long Island. Barbs on wind arrows indicate 10 knots each with solid pennant indicating 50 knots.

lina, to Cedar Island, North Carolina, a distance of about 170 miles, was destroyed. From the South Carolina border to Cape Fear, North Carolina, the destruction along the beaches was nearly complete. Whole communities were entirely demolished. Grass covered dunes from 10 to 20 feet high, along and behind which beach homes had been built, simply disappeared—dunes, houses, concrete slab floors, and all. In some places the tides were over 17 feet above mean low water.

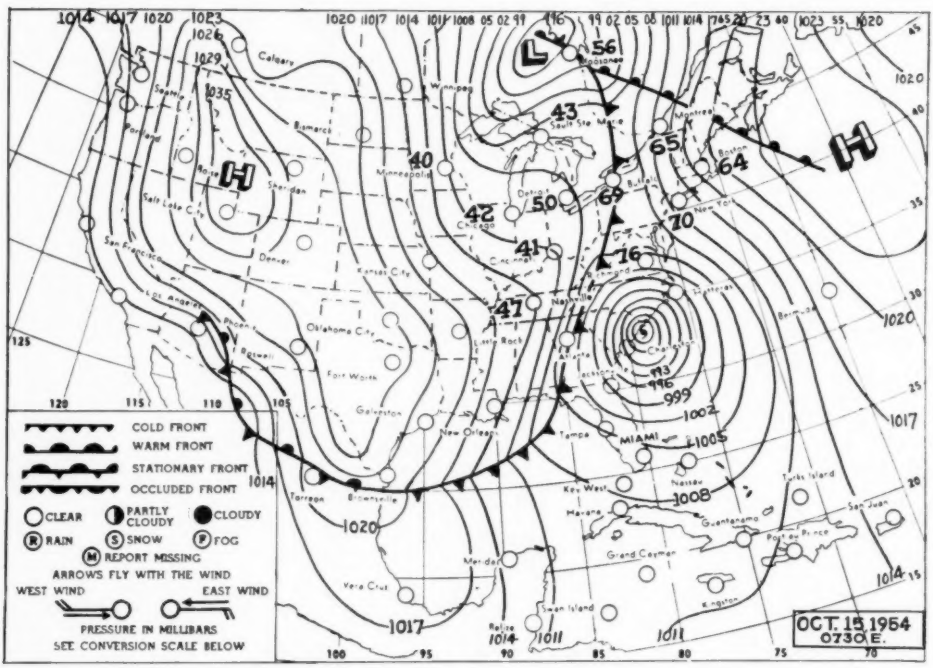
Strange objects found along the Carolina coasts after the hurricane passed included green coconuts, pieces of bamboo, large tropical clams weighing eight pounds, and a mahogany bowl upon which was carved "Made in Haiti."

Damage was great in all states from the Carolinas north to Canada. Inland, out of reach of the rising waters, an estimated one-third of all buildings in the eastern two-thirds of North Carolina received some damage. At least ten stations in North Carolina reported the highest 24-hour rainfall of record in connection with Hazel with amounts up to more than 11 inches.

Highest winds measured were at Myrtle Beach, South Carolina, where the extreme velocity was 106 mph. Winds, however, were estimated at 130 to 150 mph at many exposed places between Myrtle Beach and Wilmington.

Without the evacuation, sometimes forced, of complete communities along the beaches, there could easily have been another Galveston Disaster, for about 1,500 houses were completely destroyed besides the thousands that were severely damaged. As it was, only 19 people were killed along the beaches. Too much cannot be said in praise of the many individuals who distributed the warnings and helped people get to safer locations.

From the meteorological viewpoint the 1954 season offers at least two items of special interest: (1) the great acceleration in speed of forward movement by Carol, Edna, and Hazel, and (2) Hazel's and Carol's maintenance of



The surface chart for 0730E, 15 October 1954, shows Hazel a short distance southeast of Myrtle Beach, South Carolina. Large numbers indicate surface temperatures at several northeastern stations.

great intensity after moving into northern latitudes and after traveling over land.

Acceleration of Hurricanes

It should be mentioned that hurricanes usually move much faster after they recurve from tropical waters into the middle latitude westerlies. Most hurricanes are far at sea at the time of rapid acceleration and of little concern except to maritime interests. This year, however, the hurricanes were threatening the heavily populated areas of northeastern United States and were of vital interest to everyone. Carol, in particular, caused great speculation since for 60 hours she had a net forward speed of less than 3 mph and then accelerated to a forward speed of 40 mph. Edna and Hazel each moved faster than Carol, but their acceleration and tracks were more regular.

We have learned that the movement of hurricanes is largely controlled by the flow of air around them up to high altitudes. To illustrate the point, figure 2 shows the 300 mb map (about 30,000 ft) when Carol was located east of Jacksonville, Florida, shown by the tropical storm symbol, and was moving slowly. From the gradient of the height contours we can deduce that the air currents around the hurricane were very weak and variable in direction. If the hurricane had been farther south in the moderate easterlies, then about 20 mph at Havana, Cuba, she would have moved faster. Figure 3, for instance, shows the 300 mb map at the time when Carol was moving northward about 39 mph. Note that the gradient of the height contours indicates that the winds should be strong southerly all around Carol when over Long Island. At Washington, D. C., winds were about 55 mph at 31,260 feet, and at Caribou, Maine, they were south 35 mph at 19,000 feet. The long heavy arrow in figure 3 extending from Cape Hatteras, North Carolina, through New Hampshire into Canada shows part of the track of Carol.

The rapid movement of Hazel northward from North Carolina to upper New York State and Canada can also be explained by the strong southerly current. Winds at 35,000 ft over the northeastern states were blowing from the south with velocities ranging from 80 mph at Washington, D. C., to 200 mph over northern Michigan at the time Hazel was over North Carolina. It is little wonder that she was soon moving forward at 60 mph and faster.

Maintaining Intensity of Hurricanes

Why did Carol and Hazel maintain their intensity is our next question. Mr. R. L. Frost, of the Wilmington Weather Bureau reported that building destruction caused by Hazel was said to have been greater in the interior sections of North Carolina than at inland points near the coast; apparently Hazel started weakening after passing inland, but intensified again later. Let us see if another source of energy became available to the storm after Hazel passed inland. Figure 4 shows the sea level map when Hazel was two hours from land. Note the cold front which was moving rapidly from the west. Also note the large difference in temperatures in the two air masses which would add the potential energy of air mass distribution to the storm once the cold air reached Hazel. There is evidence that this source of energy did help maintain the storm. By the time Hazel reached the latitude of Raleigh, North Carolina, the cold air was adding energy, for the highest winds at the Raleigh Airport occurred with the cold front passage and blew from the west-northwest. Near Raleigh Mr. Carney of the local Weather Bureau reported that most trees were blown down, even on the east side of the storm's path, toward the east. "This was undoubtedly due to the arrival of the cold front at Raleigh simultaneously with passage of the storm center about 35 miles to the east," he observed.

Charles H. Pierce in his study of the New England Hurricane of 21 September 1938 pointed out that the potential energy of mass distribution of that storm, which was also joined by a cold front, was a factor in maintaining the force of the winds.

In the case of Carol there was no surface cold front, but there was strong advection of cold air at the 850 mb level as far east as Detroit and Louisville, even while Carol was still south of Cape Hatteras. Thus it is reasonable to conclude that the release of potential energy of mass distribution could have been a factor in maintaining the energy of that storm.

THE severe floods in northern Iowa and in southern Texas during the month of June were the most damaging and widespread to be reported during the year 1954. In general, it was a year of drought, in some areas the most prolonged in history, and records were set at many points for unprecedented low water stages. In parts of the Southeast and southern Plains rivers dried up completely with disastrous results for agriculture and public health.

The most significant flooding during January 1954 occurred in streams along the California coast. The Russian River reached its highest stage at Guerneville since February 1940, and at Healdsburg since January 1943. Two major floods were reported on the Eel River at Fernbridge, Calif. Considerable damage was reported from flash floods in northern Alabama; the Flint River reached the highest stage in its history in the upper portion; the Tar and Neuse Rivers in eastern North Carolina reached their highest stages since 1945.

There were no major or significant floods during February. All the overflows reported were generally light or minor. The ice on the Missouri River broke up about three weeks earlier this year than normal, and in the 99 years of record the ice has broken up earlier only five times. Record low stages were reached on the Scioto River in Ohio.

Flooding in March was mostly light or minor. The Scioto River reached a new record low during the month.

There was no significant flooding during April. All floods reported were light or minor. New low monthly mean stages were established on the Arkansas and Cimarron Rivers.

The highest stage ever recorded was reached on the Kootenai River at Bonners Ferry, Idaho, during the last decade of May. Although an unusually heavy snow cover existed over most of the Columbia River basin, the overall weather pattern was favorable for the depletion of the snow with a minimum of disastrous flooding. In the upper Mississippi basin the flooding was severe on the Chippewa River at Durand, Wisconsin.

Excessive rains from 17 to 21 June over north-central and northwestern Iowa produced record to near-record flooding in the Des Moines River basin at and above Des Moines and in the Rock, Little Sioux, and Big Sioux river basins. The four-day downpour dropped as much as 10 inches of rain over the upper portions of the Des Moines watershed. The stage at the city of Des Moines was the highest of record, exceeding the peaks of June 1947 and May 1903 by approximately three feet. The greatest losses were to farmlands; an estimated 725,000 acres of crops were under water; and losses were put at close to $10 million.

Hurricane Alice was responsible for the greatest flood in the history of the middle

The greatest flood in the history of the middle Rio Grande
tween Eagle Pass, Texas, and Piedras Negras, Mexic

Floods of 1954

ELMER R. NELSON, *U.S.*

Rio Grande has destroyed the Southern Pacific R. R. bridge be-
Negras, Mexico, on 29 June 1954. World Wide photo.

LSON, *U. S. Weather Bureau, Washington*

Rio Grande River and lower Pecos basin. As the dying storm brought vast quantities of moisture over the rising plateau of south-central Texas, some remarkable rainfall figures were set. Over an area about 50 miles long and 15 miles wide amounts exceeded 24 inches, with a top figure 27.1 inches reported at Pandale. At Laredo, Texas, a flood stage 12.6 feet above the previous highest stage was reached, and on the Pecos at the U. S. 90 highway bridge the roadway was 30 feet below the crest. Fortunately, the newly-completed Falcon Dam, which was nearly empty at this time, contained the flood waters and prevented a major catastrophe in the lower valley.

The most damaging flooding during July was the flash flood in the Gauley River basin at Richwood, W. Va., with damages estimated at approximately $2 million. Ohio residents compared the rainfall and stream flow of tributaries in the upper Miami basin to that of the great flood of 1937. Flooding elsewhere was comparatively minor. Record to near-record low stages were reached at several points throughout the country.

Drought conditions continued over extensive areas with record to near-record low river stages at several points in the Atlantic slope drainage and in the southern states east of the Rocky Mountains during August. It was the first time since 1900 that the North Canadian River stopped flowing at Wetumka, Okla. The Lake Fork River at Quitman, Texas, also dried up during the month. The most significant flooding occurred in the upper Big Blue River in Nebraska and Kansas. Flash floods were reported in West Virginia, Colorado, Utah, and Arizona.

There was very little flooding during September. The high water that did occur resulted from heavy rains that accompanied hurricane Edna in the New England states. Record to near-record low stages were reached at several points in the South Atlantic slope drainage and in the East Gulf of Mexico drainage.

The most significant flooding during October occurred as a result of the heavy rain accompanying hurricane Hazel as it moved in a northerly direction from the Carolinas to north-central New York state. To the west of the track along the slopes of the Appalachians very heavy falls with amounts up to 10 inches were reported, sending many streams over their banks. A spectacular flood occurred in the Chicago area when a front stalled over the Windy City and dumped up to 12 inches in the area in a 48-hour period. The Chicago River flooded and forced engineers to temporarily reverse its flow to relieve the pressure of the mounting waters. Traffic and business in Chicago were greatly hampered for two days. Another flood of the flash type occurred at Roswell, New Mexico.

There was no significant flooding during November or December.

Progress in the Study of Tornadoes During 1954

EDWARD M. BROOKS, *Institute of Technology, St. Louis University*

THE best opportunity to assess progress in tornado studies came at the American Meteorological Society meeting at Miami Beach, 17–19 November 1954, where the emphasis was on the subject of tornadoes. There were three sessions with tornado papers, a short session with tornado movies, and a panel discussion on various tornado problems. For the program and abstracts of the papers, see the *Bulletin of the American Meteorological Society*, Oct., 1954, pp. 381–390.

The tornado movies included Ray Davis' film of the Worcester tornado of 9 June 1953 and a commentary by the author, indicating cyclonic inflow and updraft. The other movies were of Dr. Weickmann's laboratory models, indicating a mass flux independent of the updraft diameter, or an updraft speed inversely proportional to the updraft area.

The panel discussion opened with an introductory statement by the moderator, Mr. Van Thullenar, and was followed by a talk on the tornado model by the author. After reviewing early studies of tornadoes in the 19th century, he proposed for a basic model an updraft and outflow aloft accompanied by a cyclonic inflow at the surface. For a theory of tornado formation to be judged acceptable, it must include instability in a cyclonic wind field, be in accord with a satisfactory theory of convection of an actively growing thunderstorm cell, and should show how the energy sources and sinks lead to the tornado's circulation, pressure, and temperature structure. Before the properties of a tornado can be determined for a given case, the severe storm must be identified as a tornado by use of the following criteria for a tornado: (1) pendant cloud or characteristic roar, or (2) rotating surface wind and reduced pressure effects, and (3) path sharply defined and narrow. Research recommendations were made for getting more information about the following properties of the tornado: direction and speed of tornado center, surface wind speed, ratio of radial to tangential flow at surface, updraft speed, height of top of tornado, speed of outflow aloft, and thermodynamic factors. The following aspects of the environment of the tornado also need study: dimensions of associated pressure and wind systems, measurements and analysis of surface and upper-air flows, structure of micro-low or of pressure jump, and position of tornado with respect to thunderstorm and hail.

After the author's talk, the other panel members expressed their views. Dr. Tepper spoke of the different frames of reference used in studying tornadoes, ranging from large-scale to very small circulations, and said that the various research methods were based on dynamics, thermodynamics, laboratory models, forecasting, radar and sferics, or statistics. He then proposed the establishment of an observational program similar to the Thunderstorm Project to make a detailed surface and upper-air study of a volume of air 100 miles long, 25 miles wide, and about 20,000 feet high, extending 5 miles ahead and 20 miles behind a pressure-jump line attended by severe local storms. Dr. Ligda proposed that aircraft should be sent to probe the immediate environment of a tornado as soon as it is spotted by radar. Dr. Freeman said one of the most important points in his tornado theories is that a concentration in wind shear or vorticity has to be trapped and must go into a region of updraft. He added that the aerial reconnaissance project (described by Dr. Ligda) or perhaps the ground project (described by Dr. Tepper) would cost about $500,000 per year.

Dr. Jones mentioned a spurious tornado report based on an erroneous identification of a cloud formed by cooling in a region of heavy downdraft of cold air. Dr. Fletcher suggested an analogy method of analyzing some potent dust devils in the Far West to find their wind structure and pressure distribution. He also suggested for additional

research tools the use of radioactive isotopes in the air, the collection of photographs (particularly time-lapse pictures), and the measurement of electric potential gradients. Mr. Harrison questioned the usual identification of a severe local storm only as a severe thunderstorm instead of a tornado if it produced a sharply defined and narrow path of damage (author's item 3 listed above), but had none of the other identifying characteristics of a tornado (author's items 1 and 2). In the discussion that followed, the author also favored the identification of this storm as a tornado because cases of really severe squalls confined to a width of only 200 yards would be exceptional. Dr. Ligda made a distinction between a wind that comes down and flattens everything (called a "plow-wind" by Col. Fawbush) and the tornado, which seems to blow things apart and scatter debris all over the countryside. Col. Fawbush identified the cold downdraft (cited by Dr. Jones) as the plow-wind, characteristic of isolated stationary thunderstorms. Dr. Rossmann suggested using building models in a large wind tunnel to measure wind pressures on structures.

From the floor, Mr. Mayer proposed the use of missiles for getting upper-air data. Dr. Abdullah told about a theoretical model of a tornado without rotation, but with straight inflow, which could have a minimum diameter of about 3 meters. If rotation is added to the inflow, the tornado's minimum diameter is increased to 5 or 6 meters. Another theoretical model he mentioned was a vortex without vorticity. Dr. Abdullah then described Prof. Miller's laboratory model showing straight inflow at the surface while rotation occurs above the surface. Certain obstructions were found to cause the vortex to bend away from it. Because of its compressibility air was preferred to water as a test fluid.

The next topic of the panel was tornado forecasting, led by Col. Fawbush, who illustrated a variety of circumstances of observed tornadoes: single, scattered, with moving micro-low, along a cold front, and in a broad belt ahead of a cold front. He theorized that a wide path of wind damage in the absence of a tornado cyclone can be produced just east of a micro-anticyclone by a downdraft from an axis of strong winds aloft. Mr. House, like Col. Fawbush, expressed doubt that we will be able to forecast the place and time of tornadoes in the foreseeable future. However, Mr. House expressed hope for tornado forecast improvements through better delineation of potential instability areas and better analyses and forecasts of "kicker" mechanisms which initiate tornadoes. He added that more accurate timing of radiosonde releases and of tornado occurrences is needed. Dr. Fletcher suggested that tornado forecasting is ideally suited to numerical weather prediction methods because it is objective.

The last topic, tornado detection and tracking, was summarized by Dr. Jones, who said the problem was two-fold: to learn more about the frequency and intensity of lightning in various storms, and to design better sferics equipment for presenting information in a way that can be interpreted fast enough to be useful in tracking. Dr. Bemis announced a new technique for measuring high-speed winds moving toward and away from the observer by means of radar interference between reflections from particles in these high-speed currents. Mr. Stout emphasized the importance of good photography of radar scopes, and favored as much field investigation as work on laboratory models. Mr. Jorgensen, from the floor, told of two cases where an automatic radio direction panel in an aircraft homed on a tornado. He described how even cheap direction finders can locate thunderstorms accurately.

The author concluded by speaking in favor of establishing a tornado research institute to coordinate the research of meteorologists who are interested in undertaking or continuing tornado research.

Tornadoes of 1954

A preliminary survey of tornado occurrences indicates that more tornadoes were reported in 1954 than in any previous year. Whether these figures can be attributed to an increase in tornado activity, or to a great public awareness and tendency to report funnels, is a moot question that will always remain unanswered. Over 700 reports of individual tornadoes have been received by the Climatological Services section of the Weather Bureau.

There were three major tornadoes in which damage in excess of $1 million was reported.

(Continued on page 34)

The 1954 Drought

JAMES MCQUIGG, *U. S. Weather Bureau, Omaha*

DROUGHT is a very difficult situation to define satisfactorily. A rainfall-temperature pattern that would be disastrous for one crop would not necessarily affect another. Extremely dry conditions during certain parts of the year would not affect the crops growing in one region as seriously as those growing in another. Also, there are at least two kinds of drought. The first is an "agricultural" drought, in which the amount of water available to plants is not adequate during critical stages of development. The second is one in which a long cumulative deficiency in precipitation begins to seriously affect the amount of water available in major streams, lakes, reservoirs, and wells.

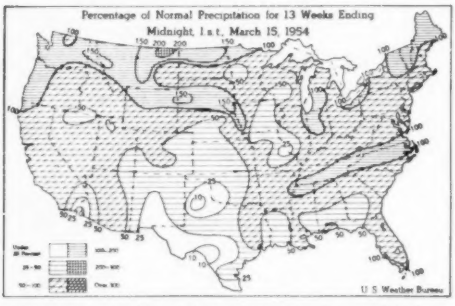
In many sections of the country 1954 began with a drought inherited from the previous year. In some portions of the Southwest, a drought situation had persisted through several years. In February drought conditions were aggravated in the central and lower Great Plains by high winds and dust storms which damaged the winter wheat that had not already been killed by drought. The large-scale atmospheric circulation during much of January and February was dominated by a strong flow from the west across the United States with most storm centers passing through Canada. In March this circulation broke down, permitting frequent outbreaks of cold air early in the month, with a return to the fast westerly flow late in the month, resulting in a "rain shadow" east of the Rockies in the latter half of the month. The precipitation pattern preceding the spring season is shown in figures 1a and 1b.

While some local areas had received drought-breaking rains early in 1954, it was not until April that the central Great Plains area got substantial precipitation. There was a major change in the large-scale circulation in May, which induced a northern flow of moist air from the Gulf of Mexico, and numerous storm centers passed through the central and northern Plains and the upper Mississippi Valley.

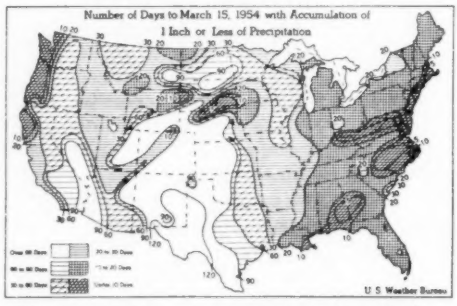
June was a month of contrasts and extremes in weather. Heavy rains fell over Michigan, Wisconsin, Iowa, southern Minnesota, eastern South Dakota, parts of North Dakota, and northern Illinois, with amounts ranging from 8 to 14 inches.

Hurricane rains in late June ranging up to 26 inches caused the greatest Rio Grande flood in history in the vicinity of Del Rio, Texas. Also parts of Arizona and southern Florida had unusually heavy falls. While these areas were getting too much rain, the drought continued to spread over much of the territory from the central and lower Great Plains eastward and northward to the Atlantic Coast and southern New England, and over the lower Mississippi Valley and Gulf Coast states. By the end of June a large high pressure area had settled over the eastern United States.

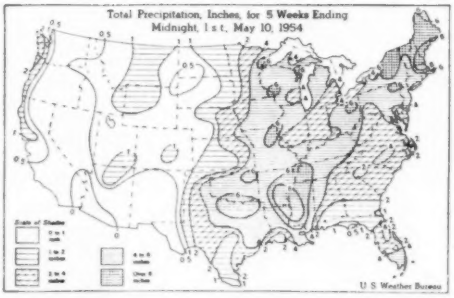
As this high pressure area slowly spread westward during July, the heat and drought in the South continued to grow in intensity. All-time record high temperatures were reported during the period from 7 through 15 July. With the exception of some temporary breaks in Missouri, parts of Kansas, and from



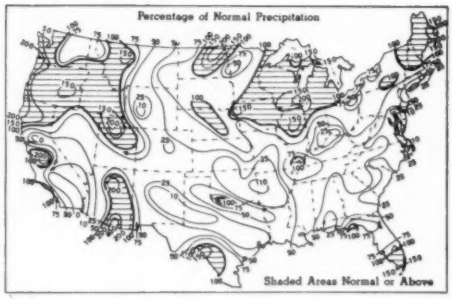
Percentage of Normal Precipitation for 13 Weeks Ending Midnight, 15 March 1954.



Number of Days to 15 March 1954 with Accumulation of One Inch or Less of Precipitation.

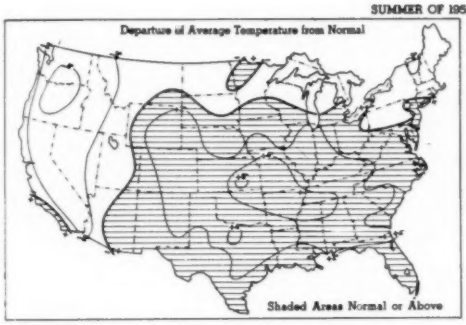


Total Precipitation in Inches for Five Weeks Ending Midnight 10 May 1954.

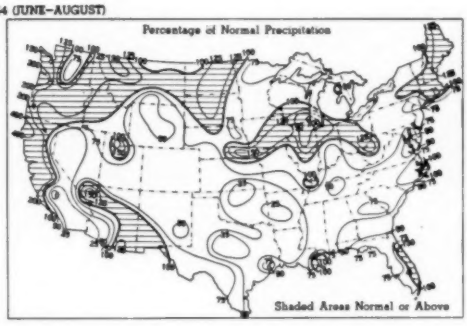


Percentage of Normal Precipitation for June 1954.

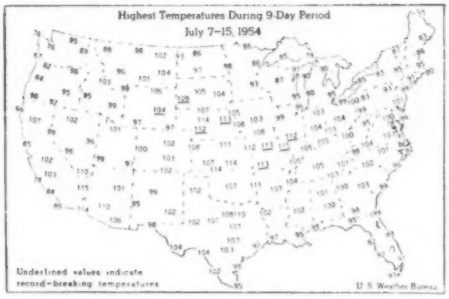
SUMMER OF 1954 (JUNE–AUGUST)



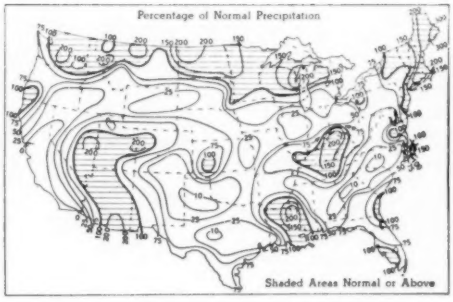
Departure of Temperature from Normal, Summer (June–August) 1954.



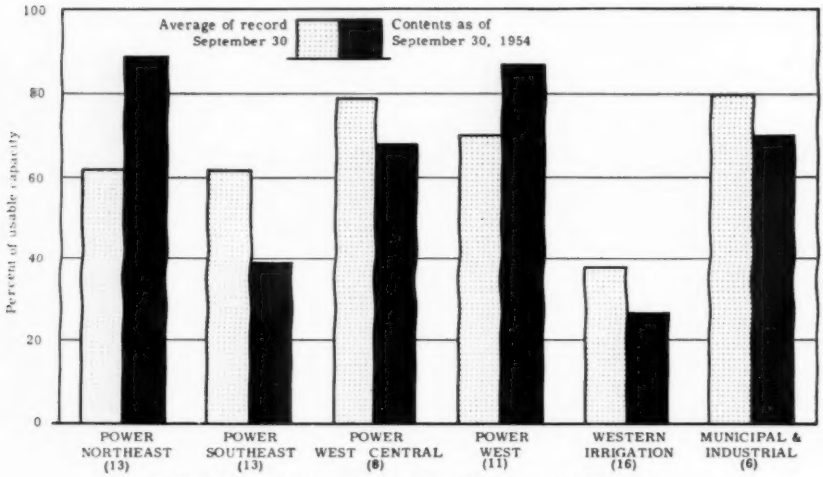
Departure of Precipitation from Normal, Summer (June–August) 1954.



Highest Temperature Registered During the Nine-Day Heat Wave, 7–15 July.



Percentage of Normal Precipitation, September 1954.

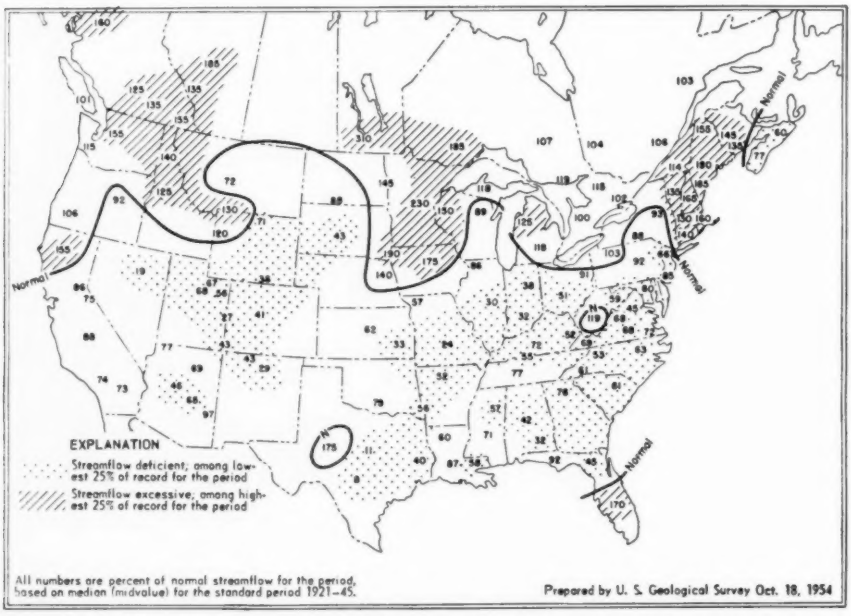


RESERVOIR STORAGE IN PERCENT OF USABLE CAPACITY.
Number of reservoirs or systems reported shown in parentheses.

those states eastward to the Atlantic Coast about the middle of the month, the heat and drought continued unabated through August. The three-month period of June, July, and August were the hottest and driest on record from Kansas, Oklahoma, and Texas to the Atlantic Coast. As one example, Little Rock, Arkansas, had 43 days with temperature of 100° or above in that period, greatly exceeding the previous record of 23 days in 1943.

September was unusually dry, except in the northern tier of states and some parts of the southwestern desert region, as the large high

(Continued on page 30)


Normal
EXPLANATION
Streamflow deficient, among lowest 25% of record for the period
Streamflow excessive, among highest 25% of record for the period
All numbers are percent of normal streamflow for the period, based on median (midvalue) for the standard period 1921–45.
Prepared by U. S. Geological Survey Oct. 18, 1954

Percentage of Normal Streamflow for Six Months Ending 30 September 1954. U. S. Geological Survey chart.

The Snow Season of 1953-54

DAVID M. LUDLUM

NORTHEAST—The snow season opened with a remarkable early season storm on 6–7 November when an energetic low moved up the eastern flank of the Appalachians and spread a record early November blanket of white from Virginia to northern New York. In much of the Middle Atlantic area it was both the earliest measurable fall and the greatest November fall of record. Depths of over 10″ were registered in a band from Wilmington, Delaware, northwestward to near Buffalo, New York. The Nation's Capital had its heaviest early season snowfall with 6.5″, but immediately to the northward the cover increased rapidly. The greatest fall was measured at Middleburg, Pennsylvania, with 27.5″. This snowfall spread into southwestern New England, but elsewhere in that section it was almost a snowless month. December, too, was lacking in snow in much of New England; Boston did not have a measurable amount in either November or December! The holiday season in northern ski resorts found slopes either bare or icy except for the highest mountain slopes.

January treated the Northeast to the most severe spell of winter weather in several years during the middle two weeks. On the 10–11th the first general northeast snowstorm since 1948 spread northward from Virginia to Maine to give coastal areas a general covering of 10″. Additional snows at inland points during the month produced January totals ranging up to 24″ in New Jersey, to 40″ in northern New York, and to 37″ in New England. At the end of the month snow cover was satisfactory for both pleasure and industry.

February, except for a three-day polar outbreak over the Lincoln Day weekend, was an outstanding mild month in the area. New York, Philadelphia, and Washington had no measureable snowfalls, usually the snowiest month of the winter at these points. The only noteworthy storm of the month moved from Lake Ontario eastward to southern Maine on the 16–18th and dropped amounts measuring up to 36″ from northeastern New York to western Maine.

March, though generally colder than February in much of the region—an unusual circumstance—continued the snowless regime of February in the Middle Atlantic and New England states. Again the major industrial cities were spared the costly problem of snow removal. But in the Adirondack Mountains of New York March proved the snowiest month in several years. Bennett's Bridge in western New York, which holds all Eastern snow records, had 70″ and Boonville was not far behind with 63″. A ma-

Damage from the glaze storm of 2–3 December 1953 at Norfolk, Nebraska. Photo by Norfolk Daily News courtesy of Norfolk Weather Bureau.

jor late season storm on 29–30 March dropped a 20″ covering over areas near Lake Ontario. Rochester had 15.6″. Snow cover in the Adirondacks reached a maximum at the conclusion of this storm. A rapid thaw, however, set in almost immediately. Boonville's 32″ on 30 March was gone by 12 April. In the Pennsylvania mountains the major cover disappeared by 4 April.

In New England the snow cover built up during March and also reached a maximum after the 29–30 March storm when falls of 18″ were reported in the north. The 42″ cover at Pinkham's Notch in New Hampshire disappeared by 20 April, as did the 23″ maximum cover reported at Greenville, Maine. In the extreme northern interior First Connecticut Lake on the New Hampshire-Canadian border reported only traces left by 27 April. Cover atop Mt. Washington had been reduced to a trace by 11 April, although there were subsequent storms later.

The season which had started with a record early season storm also added a record late season fall. On 9–10 May measurable snowfall was reported as far south as Trenton, New Jersey, and in the Poconos depths to 6″ hindered traffic movement. The storm spread across the Catskills of New York and into the Berkshires of western New England where Mt. Greylock received 12″.

MIDDLE WEST AND PLAINS—Two November storms gave much of the central Plains their earliest snow cover of record, and in parts of Kansas the month's totals exceeded all records. The disturbance of 4–7 November produced a covering up to 15″ in parts of Kansas, and later falls brought the totals to 25″ in the northwestern counties. Further east, November falls were generally above normal east of the Mississippi, especially along the lower Lake shores. In the upper Lakes, however, it was an open month. After a promising start, falls were light everywhere in the area and the snow cover largely disappeared.

January, though a very cold month during the middle weeks, was noticeably lacking in snowfall except in the vicinity of the Lakes and along the immediate northern border. North Dakota had 300% of normal in many places, while points in Missouri and Illinois continued the snowless period of the previous month. One interesting midwinter storm moved along the southern periphery of the arctic air masses over the northern Plains, dropping up to 9″ from north-central Texas, through Arkansas, to Kentucky, for the winter's principal storm in that area.

February was almost a record snowless month in all the states in the Mississippi Valley. Points in southern Minnesota and northern Iowa received none at all. The only fall of consequence left about 8″ in central Kansas and eastern Nebraska, and another locally heavy fall hit several counties of Iowa on the 25th with up to 12″. An interesting brown snow fell in parts of Wisconsin and Michigan as a result of the great dust storms on the Plains around the 20th.

March, however, brought a distinct return to winter throughout the area and amounts were generally well above normal for the first spring month. It was especially heavy along the south shores of the Lakes. Cleveland had its greatest late season storm on 28 February–1 March with a fall of 15.1″, and this was followed by 5.7″ on 2–3 March. In Kentucky the same disturbance left 18″. Chicago, too, was in the snow belt with two important falls: 11.8″ on 2–3 March and 7.7″ as late as the 29th. Bergland, the usually snowy spot in upper Michigan, had the maximum monthly total with 50″ in March.

ROCKY MOUNTAINS—There were no unusual early season snow storms in mountain or Plateau areas. Falls were far below normal in Montana where less than one inch was general. In the southern Rockies two storms brought moderate cover on the 4–7th and again on the 18–21st to give parts of Colorado and northern New Mexico double the usual November cover. And December, too, followed the same pattern with central and southern regions having above normal amounts while Montana and Idaho and much of the Plateau were far below normal.

January was a very cold and snowy period throughout the northern Rockies and much of the southern Plateau, but between these areas there were places that received little snow. Moran in northwestern Wyoming had a total of 99″, and amounts exceeded 100″ in the Divide country of Idaho and Montana where a fluctuating front lingered most of the month. Rogers Pass, which set a new low U. S. temperature record on the 20th, had a snowfall of 115″ for a very wintry setting. The month's end saw snow cover of moderate proportions over all the area except a strip from southern Wyoming south to the Mexican border.

To reverse conditions from the previous month, February set records for the least February snow on record in Utah and Colorado, and other states were not far behind. Only high mountain elevations received adequate cover. Moran had 65″. At the end of the month half of Montana was snowless, and rivers were breaking up after the warmest February of record.

In tune with the rhythmic swing of 1954's weather pattern, March produced cold and snow over the central and northern Rockies. The worst storm of the month and season was a near-blizzard in eastern Wyoming and Colorado on the 11–13th. Snow cover exceeded 70″ at the end of March in the northern mountains. A severe storm over Montana-North Dakota on 28 April left 10″ as a final gesture of a peculiar winter. The end of April when the snow stakes are usually measured found above normal pack over the north, but cover was far below normal in the south. A record low of 40% of normal in the Colorado drainage basin was reported, virtually none was left in New Mexico, and in Arizona the pack was near the minimum of record.

PACIFIC STATES—Snow was generally late in coming to the southern sections of the Pacific Coast mountains. In November Soda Springs, a traditional snow spot in California, had 30.5″, but amounts were much lighter in December. January saw the commencement of the real snow season with most northern sections receiving some very heavy falls. Snoqualmie Pass in Washington had a January total of 251″, and Crater Lake in Oregon reported 216″. Snowfall in January reached all the way to the coast in southern Oregon. The major cities of the Northwest had amounts near 20″ during the month.

A snowfall map for the winter season of 1953–1954. Solid line shows the approximate southern extent of reported measurable snowfall. Figures in each state are the maximum seasonal fall in inches reported at cooperative stations of the Weather Bureau.

In California amounts were below normal generally in January, and February, too, proved to be one of the least snowy and mild winter months on record in the Pacific area. Totals were almost everywhere below normal and in many instances only 50% of normal. At the end of February Snoqualmie reported a pack of 141″ and Crater Lake had 121″, thanks to the heavy January falls.

Whereas January had favored the northern

(Continued on page 34)

Weatherwatch

Westerly Flow Controls the Early Winter

DAVID M. LUDLUM, *Editor*

The passage of hurricane Hazel northward from the tropics to the Arctic in mid-October was the dramatic event that signalized the change in the general circulation pattern from the long-continuing summer type to the regime that was to mark the first half of the winter. This is the usual time for such a change in the flow of the weather elements, but the unusual feature of the last six months of 1954 was the persistence of one type from June until well into October, and then a similar persistence of the winter type into January of 1955. Thus, the country at large was treated to a rather steady routine of weather behavior in each period.

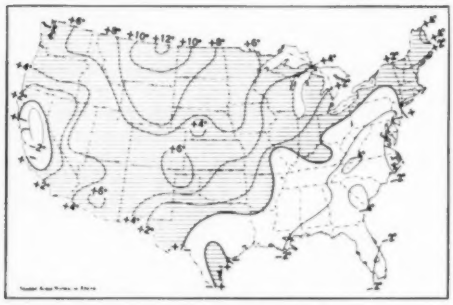
The great continental anticyclone over the Southeast and lower Mississippi Valley, which had generated the hottest summer on record in parts of the Southeast and South and continued summer heat into early October, gave way with the rearrangement of the upper-air circulation attending Hazel's activities. The institution of a familiar winter pattern found a ridge over the Plateau area with a very well-marked Great Basin high dominating the region. The Azores high was strong and in a normal position. Centers of cyclonic activity, as might be expected with a high index of westerly flow prevailing, were located south of Iceland and over the central Aleutians.

The dominant feature of the mean pressure maps for November and December, however, was the strong polar vortex which was located over Baffin Land and Denmark Strait in November and little further northwest over the Canadian arctic archipelago during the following month. The recent establishment of a first-class weather station with excellent communication facilities at Thule in northwest Greenland has permitted weathermen to keep the polar vortex under much closer surveillance than heretofore, with important gains for hemispherical weather forecasting. It is interesting to note that a strong polar vortex was in evidence during the fall season when three major hurricanes took a course almost due north instead of recurving to the northeast on the usual track.

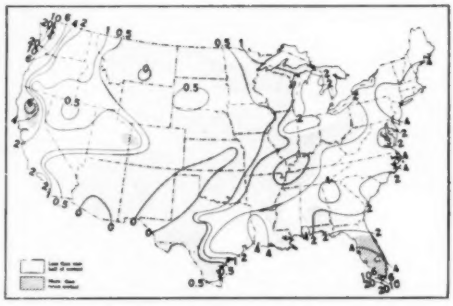
The weather pattern such as existed during early winter with a ridge over the Plateau states and a trough in the Eastern part of the country did not produce spectacular weather events. Pacific air dominated the scene with a strong westerly flow which discouraged air mass mixing and subsequent cyclonic activity. This was a dry pattern for most of the country. Onshore winds on the immediate Pacific Coast brought rains to the Washington-Oregon-northern California coastline, and rainfall was heavy there in early winter, but not unusually so. The air then moved through the western ridge with an anticyclonic trend and descended onto the Plains as a dry air mass. This air movement was encouraged by the deep cyclonic vortex over northern Canada, which had the effect of preventing any anticyclonic build-up or storage of a reservoir of cold air in the Arctic. Hence there were no major outbreaks of polar air into the United States during the period. The principal feature of the weather map in the U. S. was the unusual persistence and strength of the Basin High. Throughout December it stood firm, and occasionally built up to extreme pressures. On the 18th the center reached 1049.7 mb (31.00 inches) at Salmon Falls, Idaho, and 1049.5 mb at Pocatello.

The strong northwest flow from the western ridge into the eastern trough brought the dry air

MONTH OF NOVEMBER 1954



Departure of Average Temperature from Normal in degrees Fahrenheit. USWB chart.



Total Precipitation in Inches. USWB chart.

into the Plains. The downslope movement of this air, originally mild, was very evident in raising temperatures and lowering humidities over most of the eastern two-thirds of the country. Further, the dominance of westerlies aloft discouraged the movement of Gulf air northward. The Plains were once again in the grips of a droughty situation to continue further the three-year dry spell which has plagued the region. Some rain and snow did fall in Kansas and Nebraska, but at the close of the year moisture conditions remained critical for small grain in the western Plains. Generous winter rains were needed to pull the crops through the cold season until spring.

The most noteworthy feature of the temperature regime during the early winter was the great plus departures from normal in the northern Plains. Each week in November and December brought above normal readings in Montana; the warmest week was that ending on 19 December when Glasgow reported the average as much as 18 degrees above normal. General below zero readings did not occur in the northern border states until the very end of the month. At Minneapolis the lowest December reading was 6°; at many northern points zero did not occur until early January, making the season the latest on record for the occurrence of zero or below since records were commenced.

The same air flow which brought balmy readings to the Plains states and Midwest caused the reverse effect in the Southland. Any regime which permits a continued flow of northerly winds will, of course, bring below normal readings. Though the cold was not extreme, it caused much comment about changing climatic patterns as resort owners complained of the unpleasant conditions over the holidays and truck farmers suffered losses. Freezes were experienced in central Florida on 27 November and on 4, 7, 8, 11, 16, 20 and 23 December. The freeze on the last two dates was felt as far south as the Everglades. And Tallahassee in northern Florida reported freezing readings on no less than 11 days in December.

KEY WEST DELUGE—The southernmost extremity of the United States experienced a meteorological extreme when 19.33 inches of rain fell at the Key West airport in a 24-hour period on 12-13 November. The storm total amounted to 20.56 inches. This was the heaviest 24-hour amount on record; the nearest approach was a total of 13.54 inches which fell in one day in October 1933.

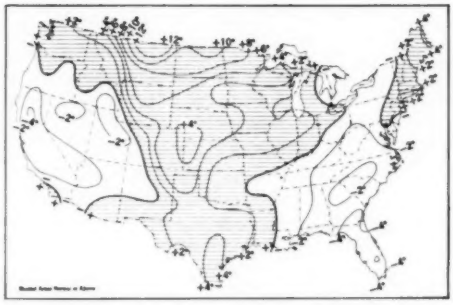
This exceptional downpour occurred along a stationary front which separated a vigorous maritime tropical air mass to the south from polar air lying over the Florida peninsula. Condensation conditions continued just right for the 24-hour period to produce almost the maximum possible precipitation. Fortunately, Key West has a natural drainage system that carried off the deluge. The same amount of water fell in south-central Texas in June 1954 and caused a disastrous flood as the water sought a way to the sea down the winding Rio Grande Valley.

The tropical air mass with sunny skies moved northward the following day preceded by heavy rainfall, and then remained over the southern peninsula during the entire four-day period of the AMS meetings at Miami Beach, so the visiting weathermen sported in the tropical delights of the resort with afternoon maxima in the 80s.

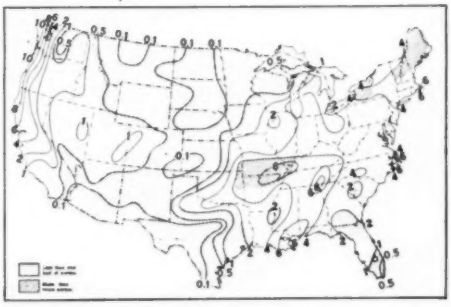
FT. SCOTT SNOW—A slow-moving frontal system that took three days to cross the Mississippi Valley treated adjacent parts of Kansas, Oklahoma, Missouri, and Arkansas to a very heavy snowfall on 26–28 December. Ft. Scott in southeastern Kansas experienced its greatest snowstorm in history with a fall of 26 inches having a water content of 3.05 inches, a very remarkable precipitation in that area for wintertime. Temperatures were just below freezing in Kansas and Missouri, but farther south the storm was all rain —Ft. Smith, Arkansas, had a total of 3.37 inches. This precipitation proved very beneficial to crops in the southeastern Plains, but did not reach in quantity to the west where moisture was sorely needed.

This storm system moved eastward on the 28–29th, bringing heavy rains to all eastern sections with the exception of northern New England. A secondary formed on the Atlantic Coast on the 30th and gave generous snows to the ski resorts in the Northeast to provide excellent snow conditions for the New Year's holiday.

MONTH OF DECEMBER 1954



Departure of Average Temperature from Normal in degrees Fahrenheit. USWB chart.



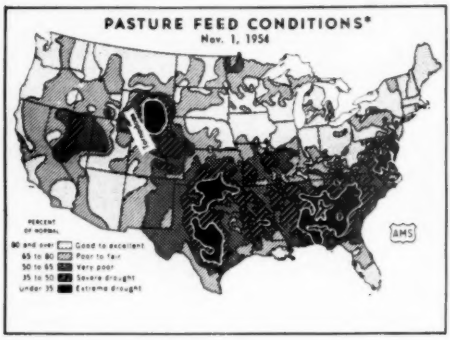
Total Precipitation in Inches. USWB chart.

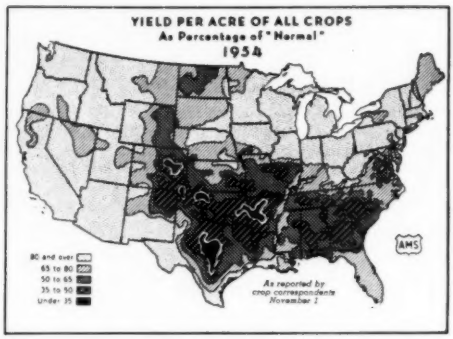
Drought (*Continued from page 24*)

pressure area persisted over the eastern United States. In parts of Louisiana, Mississippi, Kentucky, and Tennessee heavy rains fell late in the month. South Carolina, which was one of the hardest hit drought states, reported the lowest September rainfall of record.

The pattern changed in mid-October, with generous rains in the eastern two-thirds of the country except in the Southeast, as shown in figure 7.

The effects of drought on the economy of the nation are very complex and far beyond the scope of this article. However, the effects on yields of major crops have been tabulated, and are shown in figure 8 (USDA chart). The effects on pasture conditions are presented in figure 9 (USDA pasture chart). The cumulative effect of precipitation deficiencies on water supply in wells and streams is well illustrated by figure 10 (USGS 6-month average as of September 30).





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Report of the Executive Secretary for 1954

ONE of the most productive sources of historical material in the field of meteorology and of the American Meteorological Society is found in the early issues of the *Bulletin of the AMS*. During that period many of the Society's activities were under the tutelage of Dr. Charles F. Brooks, who was appropriately honored by the Society at its 135th national meeting in New York. Dr. Brooks received the Society's Award for Outstanding Services by an Individual to the Society "for a lifetime of devoted and untiring service to the Society, notably as its organizer in 1919, as its secretary for the next thirty-four years, and as editor and mainstay of the *Bulletin* for most of its first twenty years."

As chairman of the Society's Membership Committee in 1920, Dr. Brooks stated that "the aims of the Society can be realized best with the largest backing of interested members. In so far as we fail to reach those who might become backers of our projects, just so much short of our possibilities shall we fail."

The words of Dr. Brooks have been reiterated many times. On 29 December 1920 there were 903 fellows and members. On the same day in 1954 there were 5143 members in all categories of Professional Member, Member, Student, Associate, and Corporation Member. I am sure that Dr. Brooks, who retired as secretary during the Society's 35th year, is satisfied with the possibilities that have been realized. Let us look at some of the results of the Society's aims, in current operation and where there are gaps.

There is still a very large number of professionals and nonprofessionals who are solicited regularly for membership. It is only within the student and amateur groups where response is always good without too much effort. Through lists of weather personnel from organizations concerned with meteorology, local branch memberships, meeting attendance records, authors of articles in the Society's publications, and purchasers of AMS publications, an extensive "nonmember" file has been growing during the past six years. Revisions and additions are being made to this file daily for the current mailing of National Science Foundation Questionnaires to ensure that as complete coverage as possible is obtained for meteorology in the National Register of Scientific and Technical Personnel. While all lists have not been processed, 3140 nonmembers have already received questionnaires. This number will be increased considerably by the deadline for circularization in the spring. Yet it is an appalling figure, as it now stands, in that so many fail to recognize their responsibility to the profession by supporting the Society through affiliation.

On the positive side, the notably increased membership since the Society became a professional organization in 1944 has aided in extending membership services, increasing the number of publications from one to six, appointing 24 committees whose reports along technical lines are sought frequently by those in allied fields, and enabling the Society to speak more authoritatively for the profession.

It would appear from correspondence and discussions that the Employment Service is probably of greatest interest to members among the Society's services. There are now 200 members requesting information on current job opportunities. Employment bulletins are mimeographed as job listings are received, and the mailings are on the average of once a month. Some employers express the opinion, and those in the universities agree, that there are still shortages of research meteorologists.

Directly the Society can assist by representing the interests of all concerned in stimulating young people to enter the field. One example is the distribution of the October 1954 "Schools Issue" of *Weatherwise* to 27,000 high schools in this country for the attention of science departments. Another is responding to the large number of requests for guidance literature about meteorology; these needs are met currently by mailing of the October 1953 "Careers and Education Issue" of *Weatherwise* and a reprint of four articles from the "Schools Issue," plus brochures about the publications and services of the Society. The requests for guidance literature average 60 a month. One university's department of meteorology has ordered

200 reprints from the "Schools Issue" for its own needs.

The six publications of the Society certainly represent a very broad coverage of developments in the field of meteorology, but there is room for improvement. Many members have expressed the need for more articles on climatology, applied meteorology, and inclusion of more notes, news, and announcements of general interest.

The *Bulletin* will undoubtedly undergo some revision in the change of editorship now in process, and it is hoped that more news of local branches, corporation and individual members can be included. The Professional Directory in the *Bulletin* will exceed the usual one page in the 1955 volume, indicating more activity in private weather services. Commercial advertising has also increased in number of pages and quality. The 1954 *Bulletin* included eight meeting programs.

The *Journal of Meteorology* continues to enjoy its excellent reputation. There were 28 more pages in the 1954 volume than in 1953, and Editor Baum indicates that there are still more articles awaiting publication. Two special issues were included in the 1954 volume of *Weatherwise*, "Instruments Issue" and "Schools Issue." Nos. 7 and 8 of *Meteorological Monographs* appeared in 1954, "The Jet Stream," and "Recent Studies in Bioclimatology." Review copies of the *Monographs* are in demand.

In cooperation with the American Geophysical Union's Committee on Cloud Physics, a recent bibliography on cloud physics was included in the July 1954 issue of *Meteorological Abstracts and Bibliography*, thus supplementing the earlier one of March 1950. The Editorial Offices of the *Abstracts* project are in Washington, D. C. The *Abstracts* are published through support and sponsorship extended by the Geophysics Research Directorate, Air Force Cambridge Research Center, Air Research and Development Command. The Translations Project, with offices at 3 Joy Street, Boston, is under contract with the Geophysics Research Directorate also. Alphabetical lists of translations are available on request.

In addition to the regular publications of the Society, the *Proceedings of the Toronto Meteorological Conference of 1953* were made available to members at reduced prices. Work on the preparation of a new *Meteorological Glossary* is progressing satisfactorily but it is somewhat behind schedule. The *Glossary* will be published by the Society through support and sponsorship of the U. S. Weather Bureau and Department of Defense. The editor's office is at 3 Joy Street, Boston. In addition to the editor and consulting editor, there are some twenty collaborators used in preparing a breakdown of seventeen fields. Definitions in each field will be reviewed further by other experts. Publication date is still indefinite for *Dynamic Meteorology and Weather Forecasting*, by C. L. Godske, T. Bergeron, J. Bjerknes and R. C. Bundgaard, to be published jointly by the Carnegie Institution of Washington and the Society. Under consideration are *Meteorological Research Review*, a survey of recent accomplishments in certain fields outlined in the *Compendium of Meteorology*, and *Progress in Meteorology*.

Whenever it is possible to do so, members receive reduced prices on Society publications. All regular publications of the Society, except the *Monographs* are mailed directly to members and subscribers as issued from the press, since addressograph facilities for such large mailings are not available at the location of members' records.

Occupying the fourth office of the Society at 3 Joy Street, Boston, is the National Register Project of the National Science Foundation. Members and nonmembers are receiving questionnaires, and a total of 7823 were mailed at the end of December, 1954. Because the response from members in the first mailing was only 46%, a follow-up will be distributed to nonrespondents in January. Other societies participating in the Register are: American Chemical Society, American Geological Institute, American Institute of Biological Sciences, American Institute of Physics, American Mathematical Society, American Medical Association, Federation of American Societies for Experimental Biology, American Psychological Association, Engineers Joint Council, American Veterinary Medical Association. Representatives of the AMS attended two meetings in Washington, D. C., in October about the Register at the invitation of the National Science Foundation. While members' personal data in the

records of the Society are very complete and are brought up-to-date by the directory-of-membership form on the annual dues statement, National Science Foundation Questionnaires will provide a little more pertinent information. Therefore, when the first stage of work for the Register is completed, plans can once again be considered for a directory of Society members in the fall which has been unavoidably delayed in the past because of other work priorities.

Seven meetings of the Society were held in 1954 and the same number is on the calendar for 1955. The Society met for the first time with the Society of American Foresters at the 134th national meeting in Berkeley, California, in conjunction with the AAAS, making a total of thirteen organizations with whom the Society has met as joint sponsor. Attendance at the 1954 meetings was much greater than anticipated. Particularly fine reports have been written about the Berkeley and Miami meetings which will be a challenge to any group handling the local arrangements for future meetings.

Advance publicity of meetings is made through the *Bulletin* and publicity releases, a list of 700 names receiving the latter. The publicity-release list includes other societies, editors and science writers of technical, scientific and popular magazines, newspapers, radio-TV, colleges and universities, key distribution centers of government agencies, airlines and other appropriate industrial organizations, foreign meteorological centers, officers, councilors, committees and local branch officers of the Society. A "publicity release" might be a meeting program, announcement of a new *Monograph*, new guidance literature, statements of Society committees, or newsworthy items about pending legislation affecting meteorology. 1700 reprints of the Munitalp Essay Contest from the *Bulletin* and mimeographed announcement on "The Jet Stream" were mailed to members of the Soaring Society of America in December.

Many activities of the Society are still in the discussion stage, but we believe we can see how a strong Society is able to concentrate its efforts. The Society must continue its forward strides in the necessarily numerous directions to satisfy the interests of meteorologists now and to be prepared for the weather needs not yet realized.

Snow (*Continued from page 27*)

section, the return of winter conditions in March brought heavy falls to central Oregon and to interior central and southern California to alleviate somewhat a threatened shortage of white gold for the spring and summer. The spring runoff was gradual throughout the area so that a maximum benefit was derived from the sub-normal snow pack.

SOUTH—The main meteorological event of the winter in the South was the snow storm of 6 March along the middle Gulf of Mexico coast. An unusual combination of weather elements gave the coastal strip from northwest Florida to southern Mississippi a measurable covering of snow. As a small wave disturbance moved across the Gulf of Mexico, cold air with temperatures just below freezing was drawn into the circulation to produce the snow situation. At Milton Experiment Station a fall of 4 inches was measured, the deepest ever reported from the state of Florida. The previous record was 2" at Pensacola during the great cold wave of February 1899. At Mobile a fall of 2" was the greatest snowfall of the present century and the heaviest ever in March. The all-time mark for Mobile is 6" in February 1895. Most of southern Mississippi and parts of central Louisiana were also blanketed with snow. The greatest total in Mississippi was 3.9" at Liberty.

Tornadoes (*Continued from page 21*)

The most destructive took place on 1 June in Cottle County in northwest Texas causing losses estimated at $6.85 million. The two other million dollar twisters hit Georgia on the same day, March 13th. One traveled from Ft. Mitchell, Alabama, to Ft. Benning, Georgia, and caused losses estimated at $6 million; the other tore up Taylor County near Macon and brought destruction in excess of $3 million. There were 38 other storms which caused damage in excess of $100,000 each. Total damage for the country as a whole will exceed $40 million—a figure much below last year's record losses.

In all, 36 deaths were attributed to tornado activity, also a small figure compared to 1953. Six persons were killed on 30 May in Nebraska, and five in Georgia on 13 March. Georgia led the nation in fatalities with eight.

The peak of the tornado season came in June with 145 occurrences, followed closely by April and then May. There were tornadoes reported on 174 days of the year.

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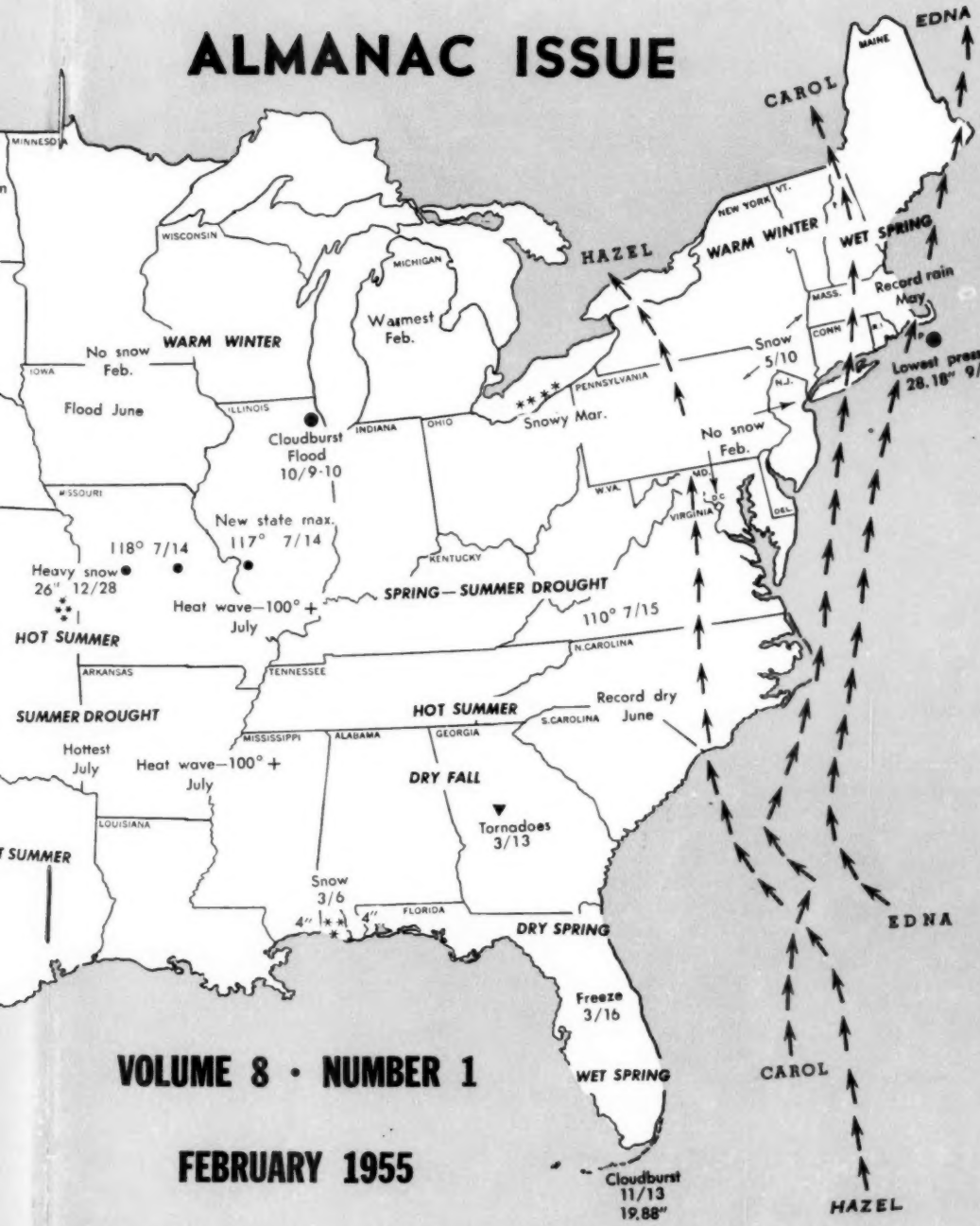

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